HYDROLOGIC SIMULATION IN A SEMI-ARID REGION

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Approved:

James R. Wallace, Chairman

Bruce H. Bradford

Gene E. Willeke

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Length

1 millimeter (mm)	0.039 Inch
1 centimeter (cm)	0.394 Inch
1 meter (m)	39.37 Inches
1 kilometer (km)	0.621 Mile

Area

1 square meter (M^2)	10.764 Square Feet
1 Donum	0.247 Acre
	1,000 Square Meters
1 Hectare	2.471 Acres
	10 Donums
1 square kilometer (Km^2)	0.386 Square Miles
	247 Acres
	1,000 Donums
	100 Hectares

Volume

1 cubic meter (M^3)	35.31 Cubic Feet
	1,000 Liters
	100 Decaliters
1 million cubic meters (mcm)	810.68 Acre Feet

Flow

1 cubic meter per second (M^3/sec)	35.31 Cubic Feet per Second
	70.04 Acre Ft. per Day
1 million cubic meters per year	1.12 Cubic Feet per Second

SUMMARY

The objective of this research was to develop a watershed simulation model which would reproduce the essential features of the hydrologic regime of a semi-arid region such as Jordan. The Jordan Watershed Model is intended to replace the empirical methods presently being used in simulating streamflow records for wadis where water resources development projects are planned.

The procedure of conducting the research was to collect all available information on soils, geology, topographic maps, rainfall, streamflow, evaporation and previous studies by various agencies and consultants. The rainfall and the streamflow data was screened and analyzed to get an insight into the major hydrologic and the seasonal charactaristics. A continuous streamflow simulation model was formulated based on the findings of the above analyses and the availability of data on the meteorological and the physical charactaristics of the region. The model was designed to accept daily rainfall and daily pan evaporation. Weighted rainfall was computed by utilizing the constructed isohyetal maps to account for the variability of rainfall pattern.

The model performs a daily moisture accounting on a system composed of infiltration, upper and lower soil moisture storages, drainage, groundwater recharge and evaporation,

components which are intended to represent the significant hydrologic processes in a rational manner. The hydrologic processes components which represent the evaporation and the base flow distinguish the Jordan model from others. Evaporation from the depression storage occurs at the potential rate. Upper soil moisture evaporation takes place at a rapid rate due to the shallowness of the soil. Progressive evaporation dries the upper soil and forms a hard layer causing the moisture in the lower soil to evaporate at a reduced rate. The location of the water table at a greater depth restricts further evaporation from the groundwater storage. The variability of base flow recession led to a development of a model component to estimate the base flow recession constant as a function of the groundwater storage.

There are 20 parameters and constants in the model. Ten parameters were selected to be optimized utilizing the Pattern Search technique. The parameters which govern a sequence of model components and those which determine the curvature of the various model component functions are the most sensitive parameters. The domination of the low flows in the streamflow records suggests utilizing the sum of the absolute values of the errors rather than the sum of the squared errors as the objective function in the optimization runs.

For the two basins for which results are presented in this study, the model was successful, on the average, in simulating daily flows, except where the observed streamflow values are questionable. The model gave better results in reproducing low flows than flood flows. Streamflow simulation was more successful on a monthly basis than a daily basis. The errors in simulation resulted both from the approximity of the hydrologic processes representation and from the errors in rainfall and streamflow data. The streamflow records which are characterized by low flows suggest utilizing the average absolute value of simulation error rather than the standard error of prediction as a statistical tool for measuring the level of accuracy of the simulation results.

For the five years of record (1969-1973) for the Zerqa River basin, the average value of each element of the basic hydrologic equation, expressed in a percentage of the average annual rainfall, was estimated as two percent surface runoff, three percent groundwater recharge, 92 percent evaporation, two percent losses to seeps, spring, and deep aquifers and one percent increase in the soil moisture storage.

The importance of this research, being an initial attempt to study the hydrological cycle of Jordan based on approximate mathematical representations of the major hydrologic processes, is that this model offers a significant improvement to streamflow simulation methods presently being used. This research provides a study of the hydrology of a region that has received very little prior study and is useful in understanding the major hydrologic processes in such a region.

CHAPTER I

INTRODUCTION

A detailed knowledge of water resources of any country, including their occurrence in place and variability in time, is essential to attain the maximum efficiency in the exploitation and management of those resources. The problem is acute in Jordan, being an arid and semi-arid region, where 87 percent of the country receives an average annual rainfall of less than 200 mm, and the remaining 13 percent receives an average of 370 mm rising to a maximum of 600 to 700 mm in the highlands.

The largest sources of surface water of Jordan are the Jordan and the Yarmouk Rivers. The headwaters of River Jordan are increasingly utilized by Israel, and the river itself is too saline downstream of Taberias (Sea of Gallilee) to be suitable for intensive usage such as irrigation. The Yarmouk River is partially utilized by diversion through the East Ghor Project which was implemented in the sixties. International considerations prevent Jordan from obtaining in the maximum benefit from this source, as most of the watershed area is not in Jordan. Thus the development of the remaining surface water becomes essential to the development of the country.

It is necessary to identify procedures used to determine the different elements of the hydrologic cycle, such as infiltration, recharge to groundwater storage, evaporation, flood runoff and base flow. It is also necessary to examine the methods used by various consultants and agencies to predict missing streamflow records of wadis where water resources development projects were planned or implemented.

Previous studies have been made to estimate groundwater flow, runoff and evaporation to establish their ratios to the rainfall. The earliest investigation was made by M. G. Ionides,[1] Director of Development in then Trans-Jordan, in 1939. Estimation was based on rainfall records, groundwater, which was considered to comprise all water flowing from measured springs or seepage, and streamflow records. Average ratios were computed for different regions, and selected basins are summarized in Table 1. It was reported that direct runoff ratios vary greatly from year to year. It varies for Yarmouk River Basin from 1.5 percent of the rainfall in 1935-36 to 17 percent in 1928-29. Variations of groundwater ratio is comparatively smaller. Clearly, the small number of rainfall stations available at that time and the accuracy of measured springs and streamflow should be considered before accepting these findings.

Another hydrogeological analysis of the Yarmouk River Basin was initiated by Burdon,[2] assigned by the Food and Agriculture Organization of the United Nations to the Government of Syria to assist in the development of their groundwater

Table 1. Estimated Annual Average Percentage of Runoff to Rainfall.

Name of Basin	Period of Record	Ground Water	Direct Runoff	Total
Northern Region*	1934-1936	7.4	7.9	15.3
Central and Southern Region**	1934-1936	5.2	5.5	10.7
Total or Average, Whole Trans-Jordan Basin	1934-1936	6.3	6.7	13.0
Yarmouk River Basin	1926-1938	9.6	8.6	18.2
Upper Jordan Basin	1921-1938	19.0	21.0	40.0

*Northern Region comprises: River Yarmouk and Wadi Zerqa River.
**Central Region comprises: Wadi Wala and Wadi Karak Basins.
Southern Region comprises: Wadi Hasa and Wadi Araba Basins.

resources. The analysis was based on the measurement of springs and recorded streamflow in the entire watershed. Calculations showed that the total runoff was 19 percent of the rainfall, of which ten percent was infiltrated water issued as springs and nine percent as surface runoff. The corresponding figure for evaporation was 81 percent. This conclusion was in agreement with the previous results obtained by Ionides.

Investigations performed by consultants[3] showed that rainfall falling on the northern region of the East Bank of Jordan was largely evaporated from the soil surface. It was reported that 88 percent of rainfall was lost due to evaporation during the periods studied.[4] Out of the remaining 12 percent, eight percent infiltrated to groundwater storage mostly reappearing as base flow or spring flow and four percent was shows as surface runoff.

Based on data filed with the Hydrology Division of the Natural Resources Authority of Jordan, Underhill[5] calculated the regional and the country water balance. The flood flow, evaporation and recharge percentages of rainfall are of questionable reliability. The estimates of groundwater recharge were computed by subtracting evaporation and flood flow from rainfall. Evaporation rates were calculated using Penman's formula. The investigator realized this unreliability and recommended the the figures are of qualitative value only and should not be used in quantitative studies. A similar analysis was made to estimate water balance in Jordan by R. L. Raikes and Partners,[5] a consultant to the Jordanian Government. Great variations and discrepancies are noted in both reports.

Finally, the linear equation of the form

$$\text{Recharge} = A\ (\text{Annual Rainfall} - B) \tag{1}$$

has been used in Jordan. Experience suggests that, by selection of the values of the constants A and B, the minimum value of annual rainfall before recharge occurs is greater than 360 mm. Studies made by Sir M. MacDonald and Partners showed that no recharge was produced from 387 mm of annual rainfall, in one case, and, in another case, 231 mm gave a small recharge. These findings illustrate the inconsistencies resulting from using such an equation.

Baker-Harza Synthetic Hyrdograph

During the period 1952-1955 a major development plan was proposed for the Jordan-Yarmouk Valley by Michael Baker, Jr., Inc., and the Harza Engineering Company.[6] The method of synthesizing streamflow used by the consultants utilized recorded rainfall and the historical streamflow of the Wadis. Streamflow was separated into base flow and storm runoff. To synthesize base flow, a curve was plotted to relate the effective rainfall of the rainy months to the base flow of the stream one month after the end of the rainfall season.

Effective precipitation was computed as a portion of the previous year's rainfall or fraction of several preceding consecutive year's rainfall. From this relationship the base flow one month after the end of the rainfall season can be obtained for any year by computing the effective precipitation. Then it becomes possible to obtain the values of the base flow in the summer months utilizing the depletion curve. The depletion curve is obtained by plotting the base flow of historical data at the beginning of the dry season, versus time in days. Separation of flood flows from base flows during the wet season is based on the assumption that base flow increases at a uniform rate from the base flow value at the beginning of the rainfall season to the base flow value at the end of the rainfall season. All flows greater than this amount during the winter were considered as flood runoff. Three relationships were thus obtained, base flow versus time, for the dry season, base flow for the wet season and flood runoff versus average rainfall in the basin. These relationships were used to predict monthly base flow and flood runoff during the dry and the wet seasons.

All the developed relationships established from the recorded rainfall and streamflow were used to extend the streamflow record at the irrigation headworks for the various wadis. Given monthly rainfall, the monthly base flow and flood runoff could be computed for any particular year. The sum of the two flows gives the synthetic hydrograph for that period.

MacDonald's Flood Flow (Runoff) Estimation

Investigation and formulation of plans for water resources development east of the Jordan River were initiated by the consultants, Sir M. MacDonald and Partners of England,[3] between 1962 and 1964. A precipitation runoff relationship was established for all the watersheds and was used to assess the feasibility of storage of the perennial and non-perennial wadis. An empirical method was derived and used to calculate seasonal runoff for a wide range of watersheds. The approximate relationship adopted has the form:

$$P = 100/(1 + K/R^n) \tag{2}$$

where

P = runoff expressed as a percentage of rainfall

R = rainfall in millimeters

K and n are constants with values depending on the of the watersheds and climatic conditions.

The major watersheds were classified into three groups according to their size and type of climate: (A) Rift side wadis are watersheds having high rainfall and rapid runoff. Drainage areas are less than 300 sq. km. Wadi Shueib and Wadi Kafrein are typical examples; (B) Large watersheds are partly in a desert zone and partly in mountainous regions with high rainfall. Drainage areas vary between 1700-3400 sq. km. Wadi Zerqa watershed falls in this category; (C) Flat desert watersheds are located in low rainfall zones.

Drainage areas are in the range of 1300-1600 sq. km. Wadi Mujib watershed, south of the Dead Sea, illustrates this group. Values of the constants, K and n, are tabulated below for the three watershed groups:

Group	K	n
A	32,300	1.50
B	3,960	1.50
C	226	0.75

It appears from the above review that the major part of work in the field of surface water hydrology was performed either by consultants commissioned by the government to plan water resources projects or by experts from various international agencies. Hydrological analysis of several watersheds, however, were performed by various agencies in Jordan.[7,8,9]

Identification of Present Needs

Projects were planned in the past by using the existing streamflow records (if available) or by using the predicted or simulated streamflows at the points of interest. Empirical equations and rainfall runoff correlation relationships were used to estimate streamflow. The empirical rainfall runoff equation, for example, which was established by the British consultants, was the main mathematical equation used to predict streamflow data needed for assessment of storage feasibility on wadis for various water resources development projects.

Until the N.R.A. has enough trained and experienced Jordanian hydrologists, it should continue to have the support of experienced hydrologists from different parts of the world. This does not mean that the N.R.A. should rely on foreign experts to do the work which could be done by Jordanians, since the necessary experience will never be gained if the work is given only to consultants. The government services, with foreign technical assistance, if necessary, would be more efficient except in such cases where special skills are needed. The consultants do not have the background knowledge of the country that its nationals do, their costs are very much higher, and more importantly, when they leave their knowledge and experiences are lost to the country, giving the client only the final results of their work. The detailed surveys, calculations, and drawings necessary for future reappraisals are not available. Furthermore, experiences of previous consultants are ignored by incoming consultants. On the other hand, the lack of sufficient technical supervision forces the government to accept the finding of the consultants without scientific justifications. However, the efforts exerted by the consultants should not be underestimated, taking into consideration the scope of the work with the time limitations and the availability of data and information.

It could be concluded, therefore, that there is a lack of efficient procedures for estimating streamflows, enabling the country to better utilize the available surface water resources. There are many water resources projects that can be efficiently instigated for irrigations, water supply and hydro-electric power plants, if an adequate and efficient procedure is made available, provided economic and political conditions permit.

In light of the above, the Government of Jordan, realizing that development of the scarce water resources is one of the key factors in the economic development of Jordan, requested F.A.O. for an expert in hydrology to assist the N.R.A. with the establishment of a national hydrologic service, including the training of national personnel in order to arrive at an overall appraisal of the national water resources. The expert terms extended from 1961 to 1964. He recommended, in the conclusion of his report,[5] that efforts should be made to pursue applied research in order to establish more reliable means of interpretation and analysis of rainfall runoff relationships for the semi-arid Jordanian watersheds. This research is intended to contribute in fulfilling this need.

Purpose, Scope and Procedure of the Research

The purpose of this research is to introduce hydrologic modeling. A deterministic continuous streamflow simulation model will be introduced to represent the hydrologic behavior of the watersheds in semi-arid regions such as Jordan. The strategy for conducting this research was to select an existing watershed model for initial simulation and calibration. The type of rainfall data limited the model selections. The N.R.A. maintains many daily rainfall stations in various parts of the country. A few hourly rainfall gages are located in selected experimental stations. The scarsity of these stations and the discontinuity of their records during major storm events warranted the selection of the daily rainfall station records for the simulation. The continuous daily streamflow model, utilizing daily rainfall, developed by the Tennessee Valley Authority was selected for this study. The availability of the daily rainfall records for the majority of the Jordanian watersheds was the primary reason in selecting the TVA model. A description of the model can be found in several reports.[35,36,44]

The TVA model was successfully utilized in the Tennessee Valley watersheds. However, the simulation results for the Jordanian watersheds were not satisfactory. It was found that the model components which govern the surface runoff volume, groundwater recharge, base flow recession and evapotranspiration were not applicable to the semi-arid Jordanian watersheds. Therefore, several modifications of the TVA model were developed to better represent the above hydrologic processes. These resulted in significant improved simulations. The following major items which were taken into consideration in the process of development are listed below:

1. Introduction of a depression storage model component and

elimination of the interception process.

2. Development of a model component to represent moisture infiltration to the upper soil storage. The infiltration and the depression storage capacities vary linearly with the percentage of drainage area.
3. Introduction of a model component to represent the interflow process.
4. Development of two functions to represent the moisture drainage from the upper soil storage to the lower soil storage and the recharge from the lower soil storage to the groundwater storage.
5. Establishment of a relationship between the base flow recession constant and the groundwater storage.
6. Development of two functions to estimate soil moisture evaporation.

Modeling by approximate mathematical representations of movement of water in basins offers a significant improvement to the methods used in previous findings. Such a model would be useful to the Water Resources Authority in Amman and to semi-arid regions in general. The Authority has expressed an interest in hydrologic modeling suitable to their situation. In addition, the Arab Center for the Studies of Arid Zones and Dry Lands expressed the same interest and inquired as to the possibility of utilizing the outcome of this research in the semi-arid regions.

Obviously, streamflow records are vital for any water resources development project. Irrigation, water supply, and hydro-electric power plants are the most needed developments. One objective of utilizing the continuous streamflow model for a given watershed is to produce the recorded daily streamflow given rainfall, evaporation, and physical characteristics of such a watershed. In areas where the streamflow is missing, the model can be used to simulate streamflow series necessary for operational studies of storage reservoirs for various projects, thus aiding the development of surface water resources. Finally, if Jordan is going to pursue rainmaking experimentation by means of weather modification, as recommended by Huschke, et al.[10] of Rand Corporation in their research project dealing with meteorological aspects of Middle East water supply, to alleviate water deficient problems, continuous streamflow modeling can be utilized. The response of the watershed if rainfall were increased can be detected using the model. Rainfall as an input data to the model can be adjusted to represent weather modification. The water yield of a wadi can then be altered. Investigations performed by Crawford[11] showed that when rainfall rates were uniformly increased by ten percent, for three watersheds in California, Kentucky, and Australia, runoff, in percent of natural annual yield, increased considerably. This increase was spectacular for the watershed in Australia (25 percent in one year of the five year trial period). If one were to order the priorities, the management and conservation of the existing water supplies would be higher on the list than rainfall augmentation. In addition, additional research needs to be done before operational weather modifications can be a reality.

Source of Data and Information

Locating and obtaining reports and studies done by various consultants, U. S. Agencies, and U. N. Agencies was a hard task to undertake. It appeared that there were no other alternatives to successfully complete this research. The greatest assistance was given by the Water Resources Division in providing rainfall, evaporation and streamflow records and other reports which are essential to this work.

It is one objective of this research to assist individuals interested in doing related work by listing all the sources of information which were solicited. This will give a starting point to initiate further research. The following agencies and consultants were contacted, either in person or by correspondence, to obtain hydrological and meteorological data, topographic maps, reports describing hydrology, geology, soils, completed and planned water resources development projects and all other pertinent information.

1. Natural Resources Authority, Water Resources Division, Amman, Jordan
2. Water Resources Division, The Arab Center for the Studies of Arid Zones and Dry Lands, Damascus, Syria

3. National Technical Information Service, U. S. Department of Commerce, Springfield, Virginia
4. National Oceanic and Atmospheric Administration, U. S. Department of Commerce, Rockville, Maryland
5. Topographic Center, Defense Mapping Agency, U. S. Department of Defense, Washington, D. C.
6. Geological Survey, U. S. Department of the Interior, Reston, Virginia
7. Bureau of Reclamation, Office of Design and Construction Engineering and Research Center, U. S. Department of Interior, Denver, Colorado
8. Bureau of Reclamation, U. S. Department of the Interior, Washington, D. C.
9. Superintendent of Documents, U. S. Government Printing Office, Washington, D. C.
10. Agency for International Development, U. S. Department of State, Washington, D. C.
11. Food and Agriculture Organization of the United Nations, Rome, Italy
12. Liaison Office for North America, Food and Agriculture Organization of the United Nations, Washington, D. C.
13. United Nations Educational, Scientific and Cultural Organization (UNESCO), Paris, France
14. UNIPUB, Inc., United Nations Publication Sales Agent, New York, New York
15. Michael Baker, Jr., Inc. Consulting Engineers, Beaver, Pennsylvania

16. Hunting Technical Service, Ltd., A division of Hunting and Surveys and Consultants, Ltd., Boreham Wood-Herts., England
17. Sir M. MacDonald & Partners, Consulting Engineers, Cambridge, England
18. Information Exchange Center, Price-Gilbert Memorial Library, Georgia Institute of Technology, Atlanta, Georgia
19. Personal communications and interviews with individuals in the U. S. who performed work for the Government of Jordan in the field of water resources. Also information collected as a result of interviews and during two site trips made to Wadi Zerqa watersheds accompanied by Water Resources Division personnel.

It was necessary to obtain an authorization from the Vice President of the Natural Resources Authority to release data, information and reports from the Authority and from the British consultants. In addition, an authorization was obtained from the Embassy of Jordan in Washington, D. C. to enable releasing the topographic maps from the Mapping Defense Agency in Washington, D. C. A complete list of reports obtained through the above sources is included in the Bibliography.

This chapter reviewed previous investigations and analysis to determine watersheds response in order to estimate streamflow for various wadis in a semi-arid area such as Jordan. The procedure for conducting the research was outlined.

Chapter II gives a brief description of the physiographic regions, climates, soils and geology of the area. Rainfall and streamflow characteristics are discussed. Finally, the water resources of Jordan and their developments are summarized. The structure of the model and the design of its components is given in Chapter III. The results of application of the model to simulate streamflow for two watersheds is given in Chapter IV. Conclusion and recommendations are listed in Chapter V. Appendix I contains the required input data for running the model. The computer output is described in Appendix II. Finally, the weighted rainfall program and the simulation model program are listed in Appendix III.

CHAPTER II

REGIONAL DESCRIPTION

Geographic Location of Jordan

Jordan is generally arid country with a land area of about 100,000 square kilometers. It is located east of the Mediterranean Sea between longitudes 34° 52' and 39° 12' east and latitudes 29° 17' and 33° 23' north. It is bounded by Syria on the north, Iraq on the east and Saudi Arabia on the east and south (Figure 1). The Jordan River separates the east and west banks, and at some points in the west bank is less than 15 km from the shores of the Mediterranean Sea.

The Jordan River System

The river Jordan flows southward in the great rift which extends from northern Syria across the Red Sea into Egypt. Its headwaters rise on the lower slopes of Mount Hermon and flow in three separate rivers - the Hasbani, the Banias, and the Dan, before converging about 25 km above Lake Taberias (Sea of Galilee) to form the upper Jordan. Enlarged by numerous springs, the river then flows in a narrow channel to Lake Taberias, dropping over 282 meters in its short course. Emerging at the southern end of the Lake, the Jordan River is soon joined by its main tributary, the Yormouk River. Further south from that point, Zerqa River flows into the Jordan River

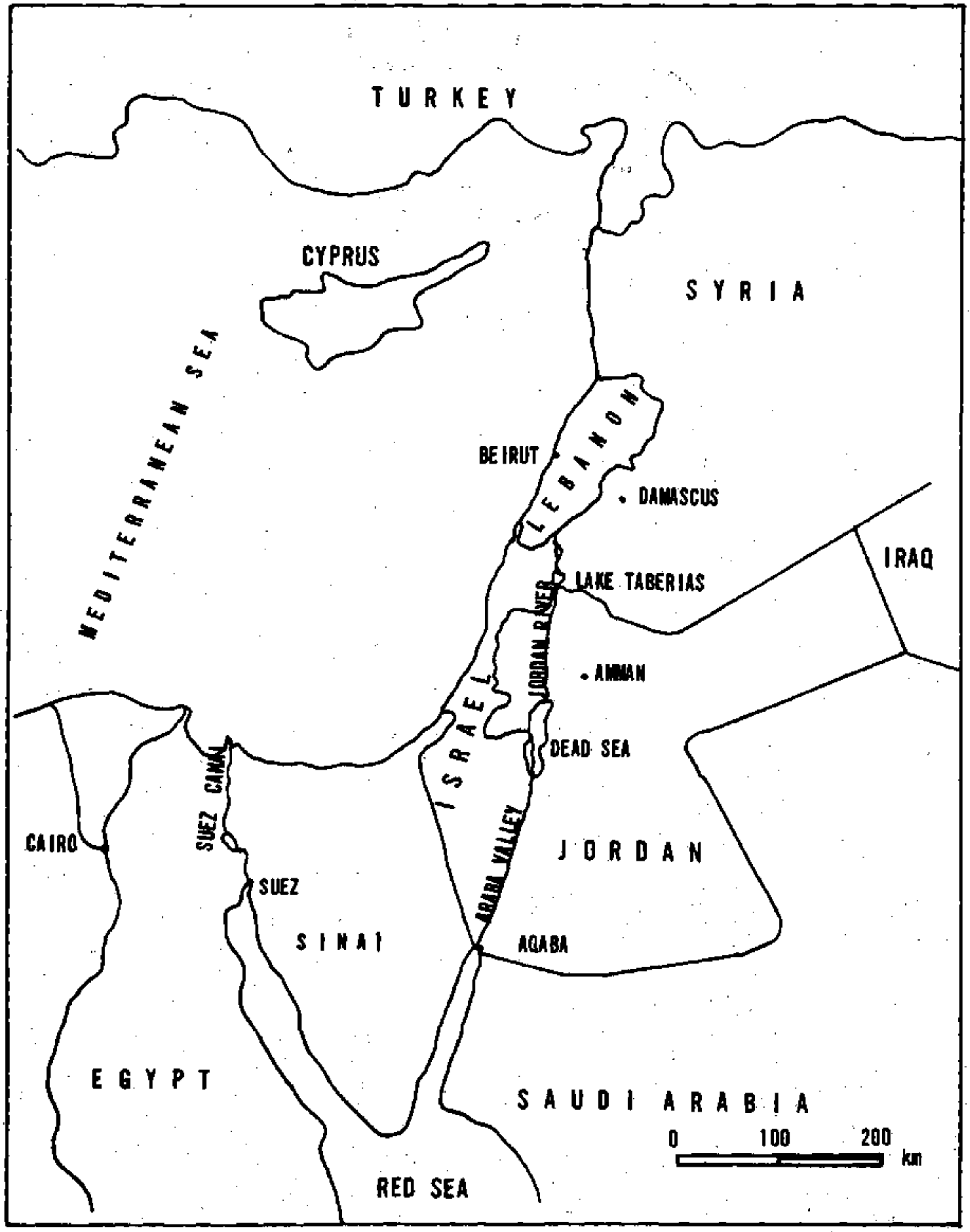


Figure 1. Location Map of Jordan.

which then flows through the valley to lose itself in the salty waters of the Dead Sea.

Physiographic and Climate Regions of Jordan

There are four main distinguished physiographic units in the country. Three regions are further divided into sub-regions to account for some unsimilarities in topography, soils, and climates. A brief description of each subregion will shed light on the topography and different climate. Figure 2 illustrates the location of each region of the country.

1. The Highlands

   a. The Western Highlands:

   This unit forms West Jordan, known as the West Bank. The crestline extends north and south which roughly bisects west Jordan. In some places in the region a summit altitude exceeds 1000 meters. The east side slopes toward the Mediterranean. The topography of this region is generally hilly. The western border from Jenin to Qalqilya is neighboring the Palestinian coastal plains and lies at altitudes less than 300 meters. Most of the remaining region is more than 600 meters in altitude. The area between the toe of slopes of the highlands and the Jordan Valley and the Dead Sea is very arid and highly dissected bare escarpment.

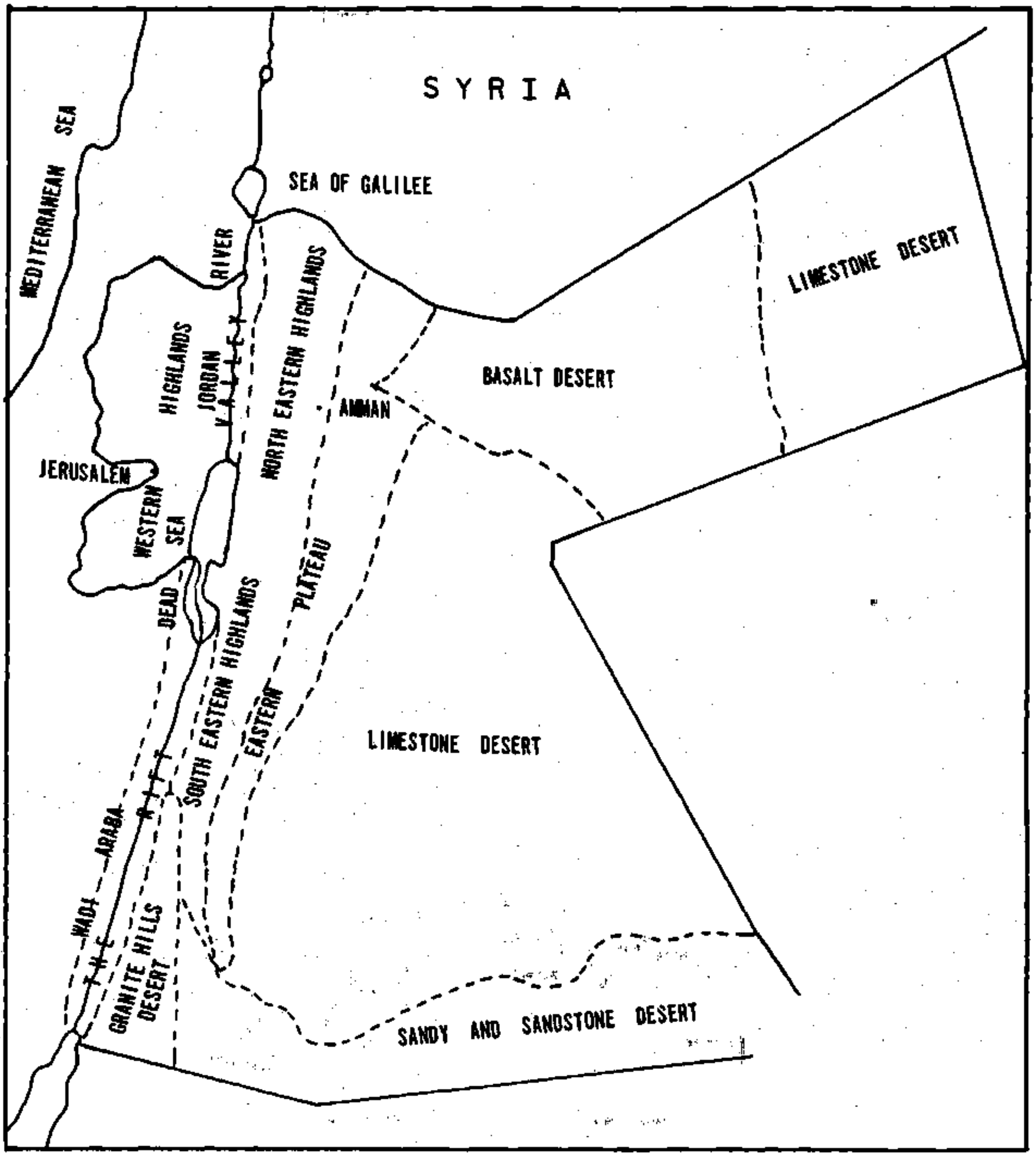


Figure 2. Physiographic Regions of Jordan.

The dominant climate is mediterranean sub-humid, with temperatures averaging three degrees C. in January to 27-35 degrees C. in August. The average annual rainfall exceeds 400 mm in most of the region and it reaches more than 700 mm in areas near Nablus and Jerusalem. Therefore, this region is considered the most productive and extensively developed part of the country.

b. The North-Eastern Highlands:

This region lies east of the Rift Valley and extends from Irbid in the northern part ot Madaba in the southern part. The Hijaz Railroad forms the boundary on the east. Wadis in the region drains westward to the Rift Valley. The characteristics of some major Wadis are spectacular where the relief along these Wadis reach about 1000 meters. Sometimes the drop from the plateau to the valley bottom is very sharp and deep. At some distance from the Rift Valley and the main river valleys, the Wadi Valleys quickly become less deep and give rise to the typical rolling country which may be seen between, for example, Amman and Swailih.

The relative closeness of the North-Eastern Highlands to the Mediterranean gives it the feature of semi-arid Mediterranean climate. Rainfall is less in amount and more variable than the Western Highlands. The average annual rainfall over the entire area falls within the 300-600 mm range. In some areas around Salt and Ajlun annual precipitation could reach 700 mm at elevations of about 900 meters.

c. The South-Eastern Highlands:

This area is located south of Madaba and extends further south near Tafila and Shaubak. Much of the land lies above the 900 meter contour and to the west of Maan there is a ridge which reaches the 1500 elevation. Part of its southern border is characterized by escarpment areas where the plateau drops down to the Rift Valley and to the southern lower lying section. The same kind of escarpment relief can be observed along the main Wadis.

The climate is arid mediterranean and very variable in geographical distribution. This phenomenon is due to the fact that the area is out of the humid air which moves from the mediterranean. In very restricted spots, such as areas around Karak and Shaubak, rainfall could reach 300 mm annually. This describes the variability and unreliability both in quantity and distribution of rainfall in this region.

2. The Eastern Plateau (Steppe Region)

This region lies mainly between the Eastern Highlands and the desert Plateau. The erosion relief becomes rapidly less important. The zone shows practically no mountain relief and is mostly rolling to undulating, although several parts of it (Mafraq area and others) are nearly flat. Only the Mujib Wadi and its affluent are deeply incised. The climate is generally arid-mediterranean with average annual rainfall of 100-200 mm. The temperature varying from 1 degree C to 40 degrees C. Dry farming in this region in some years is virtually impossible due to lack of moisture.

3. The Rift Valley

a. The Jordan Valley:

This region has the most unique feature in the country. It is considered also the most important agricultural region using irrigation practice.

In the same manner as the crestline of the west bank, hills act as a divide line, the Jordan River Valley, the Dead Sea, and Wadi Araba acts as a north-south trough across the country. The Jordan River enters the area just south of Lake Tabarias. Two principal tributaries join the river from the east, Yarmouk River in the northern section and Zerqa River in the southern section. In addition, there are many Wadis which flow from east and west to the Jordan River.

The valley slopes gradually from about 250 meters below sea level at the Dead Sea over a distance of about 100 km. There are two terraces which form the floor of the valley, the Zhor and Ghor. The Zhor is the flood plain of the Jordan River, 1-3 km wide and relatively flat. The Ghor is about 20-50 meters higher than the Zhor, with pronounced steep and badly eroded, useless land area separating the two terraces. The Ghor is narrow in the north and widens considerably as it reaches the Dead Sea.

b. The Dead Sea:

The Dead Sea is a closed salty lake whose surface water level is 400 meters below sea level, and the floor elevation at the deepest part is about 800 meters below sea level.

The basin itself lies between the steep eastern and western escarpments and has little cultivable and irrigable land. Wadi Mujib is a major tributary in this basin which is eventually lost to the Dead Sea.

The region is extremely arid. The climate is a desert type, with warm winters and hot summers.

c. The Wadi Area:

This wadi has a unique feature. It connects the Dead Sea with the Gulf of Aqaba at the tip of the Red Sea. At a point 96 km south of the Dead Sea and 75 km north of the Red Sea, Wadi Araba has its highest point of 240 meters above sea level, and from this point the Wadi slopes southward and northward to the Gulf of Aqaba and the Dead Sea, respectively.

The area is very arid and rainfall varies from practically nothing to 100 mm annually.

4. Desert Region

This area is mostly desert and comprises about 72 percent of the total area of the country. The subregions will not be discussed in this chapter.

The topography is flat in the desert area with 800 meters altitude and some hills rise from 1000-1500 meters in altitude. The land is merely plains interrupted by gravel hills with sparse vegetation of shrubs and short life grass growing in the wadi bottoms.

The drainage pattern is such that wadis drain into closed drainage areas and form depressions such as one sees at Jafr and Azraq.

Rainfall falls as thunderstorms, very intense for a short duration, sometimes causing massive erosion in some wadis.

General Notes on the Geology of East Jordan

For the purpose of better understanding soil formation and its calssification, a brief discussion of different rock formations of importance for soils will be presented here. Excellent references are available in the literature concerning the geology of Jordan.[1,12,13,14] It is not the intention of this thesis to discuss the different reports written about the geology of East Jordan. The reader is referred to the available sources for a detailed discussion of the subject. However, a very brief summary of the geology in general terms is mentioned here.

Limestone is the chief rock formation in the Eastern Highlands. Basalt rocks from volcanic extrusions are found in the north-end of the country and also in the northern part of the Eastern Desert. Nubian sandstones are dominate along the western slopes of the Southern Highlands and in the southern desert region neighboring Saudi Arabia. Granites and volcanic rocks are found in the extreme south between Wadi Yutum and Wadi Araba, extending to the Gulf of Aqaba in the south end.

The limestones are important as soil forming materials in East Jordan. On weathering, the lime is dissolved and the residue is a strongly calcareous clay or silty clay. In the wet areas this clay has a typical reddish brown color. Its free lime content can be as high as 20 to 25 percent.[15] The clay in the dry steppic and desertic areas is yellowish-brown and has a coarser texture than the limestone clay in the areas with Mediterranean climate.

The basalt is found east of Mafraq. In the dry areas the weathering of the basalt sheets has been relatively unimportant and the surface of the soils here is characterized by numerous basalt boulders. Weathering of the basalt in the arid areas gives rise to a yellowish-brown, extremely calcareous, silty clay. Weathering in wet areas gives a reddish-brown calcareous clay which, on the whole, shows the same characteristics as the limestone dissolution clay.

The Nubian sandstones are found in a large part of southern Jordan. In this desertic area, weathering of the sandstone is mainly a mechanical process. The resulting soil material is a medium to fine grained sand with yellowish to reddish colors, according to the colors of the parent rock. Along the Rift Valley and the valleys of the main side Wadis, Nubian sandstones are exposed on the lower slopes; they cover altogether a rather large area. In the area north of the Dead Sea, where the climate is no longer desertic, chemical and biological weathering, in addition to mechanical weathering of these rocks, becomes important. The weathering products of the Nubian sandstones in this area are generally not pure sand, but mostly sandy loams, loams and sandy clays.

General Notes on the Soils of East Jordan

The most important factors that function in the transformation of rock into soil, in its broadest sense, are (a) parent rocks, (b) climate, (c) vegetation, and time, plus accessory factors such as might arise from a high water table and seasonal variations in climate and in man's treatment. When rain is limited, these factors act very slowly. This explains the fact that soils in many areas are young and undeveloped.

The general features of the soils of arid and semi-arid areas, where Jordan is located, can be described by the low humus content, with very limited variation in its amounts. The scarcity of vegetation limits the amount of residue available for soil organic production. Soils are usually shallow and only slightly weathered in which soil moisture is the most limited factor. Little or no leaching is occurring due to small amount of rainfall and salt accumulation in irrigated areas where no subsurface drainage is provided. In some locations distinctive layers which often occur, such as lime, gypsum, and clay are compacted and referred to as pans and form very hard and impervious layers.

As discussed earlier, one factor in forming soils is the type of the parent rock. For example, igneous (basalt, granite), and sedimentary (limestone, sandstone, and shale) rocks are classes of sources from which soil forms. Residual soils (soils formed in place) originating from igneous rocks, and basalt differ from soils originating from sediment rocks such as sandstone. A soil derived from sandstone obviously is sandy just as a soil from limestone is clayey.

Climate is another factor in determining type of soils of the watershed. There are three general types of soil in Jordan; each type is located according to climate zones. These soils are influenced by climatic conditions on the bedrock and its effect on vegetation cover of the soil.

In areas where annual rainfall is less than 100 mm, which is considered an arid region, soils are grey desert or sierozems. These soils cover almost half of Eastern Jordan. The soil is thin and its top in many places is lime crust. The top soil differs slightly from the bedrock. The special features of this soil are that gravel, sand, or basalt fragments cover many areas.

The second type of soil is formed where average annual rainfall is between 100-200 mm. The soil consists of steppe yellow soils (Steppe is a name unknown in the nomenclature of the new world, but used in Russia to designate semi-arid plains). It is located in large areas in the eastern hills to the east of the Mafraq-Amman-Madaba axis and bounded by the foothills of the Rift Valley. The texture in general is calcareous with some brown soils. The depth of soils is roughly 50 cm with impermeable surface layers. The A horizon is thin due to the lack of humus in the area. Range vegetation is consumed rapidly due to overgrazing.

The third type is Mediterranean soils which can be further divided into two classifications: Yellow Mediterranean soil, where rainfall is the 250-350 mm range, and Red Mediterranean soils in areas which receive more than 350 mm. This type is mainly located in areas of the northern and southern Eastern Highlands. Figure 3a shows distribution of the above three general types of soil in East Jordan according to the climatic zones.

Moormann[15] subdivided the soils of East Jordan into soil groups. The soil association areas are named according to the most important soil group or groups occurring in the area. Figure 3b shows the distribution of these soil associations. A brief discussion of important soil associations is presented.

1. Red Mediterranean Soils Association

The Red Mediterranean soils group comprises more than 80 percent of the surface area where this association is located. It formed on dissolution clay of limestone. The soil is relatively deep in the valleys and in areas of high rainfall. The texture is mainly clay or clay loam throughout. In shallow soils, hard fissured limestone is situated approximately 50 cm deep, whereas in areas 100 cm below the surface with deep soil of hard consistency, very calcareous clay or clay loam are found. The important soils occurring in this association are the limestone lithosols soils. This group of soils comprises lime outcrops as well as very shallow soils over the rocks. Lithosols soils comprise about 15 percent of this association.

In high rainfall areas where the Red Mediterranean

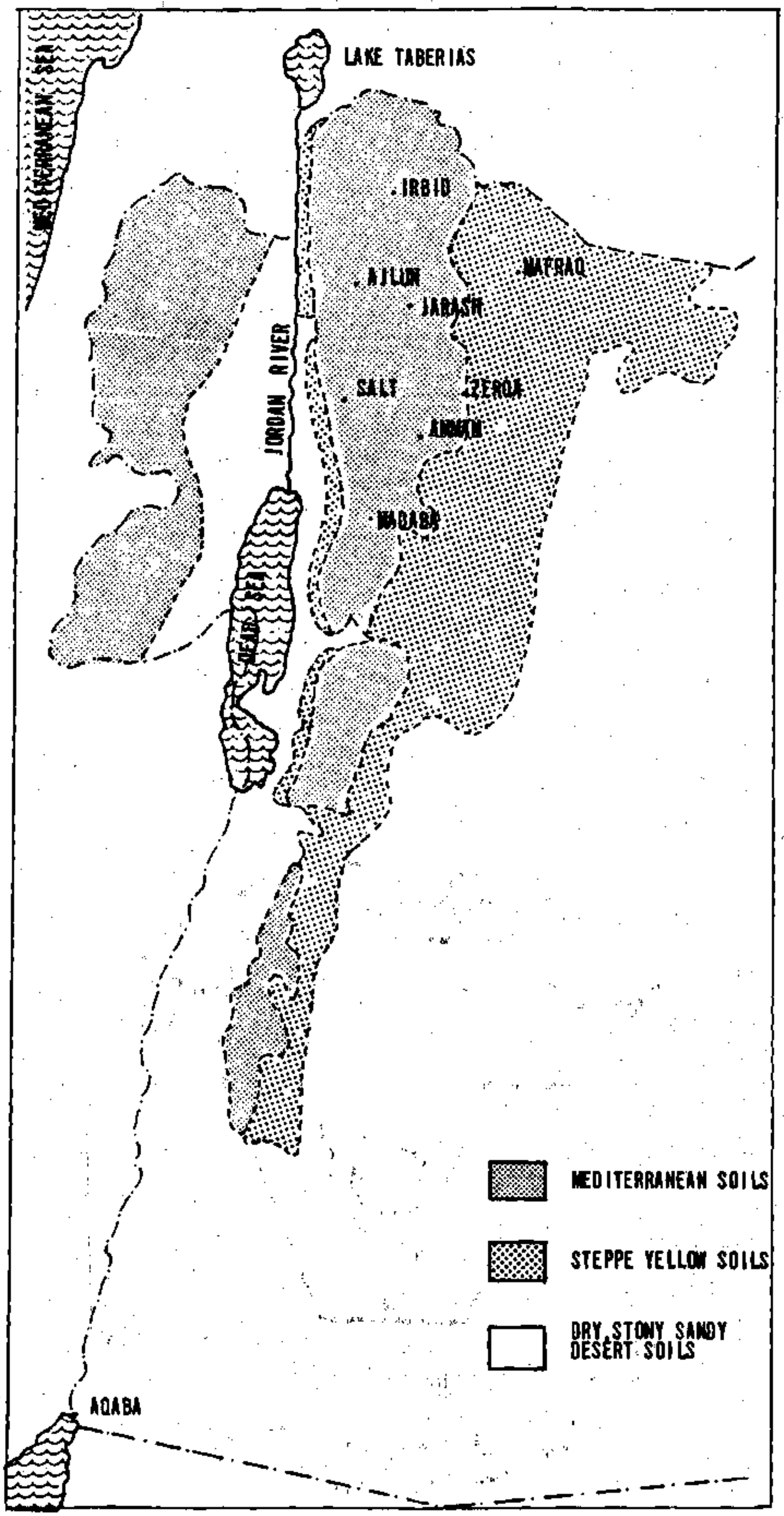


Figure 3a. Distribution of the Soil Types in Jordan.

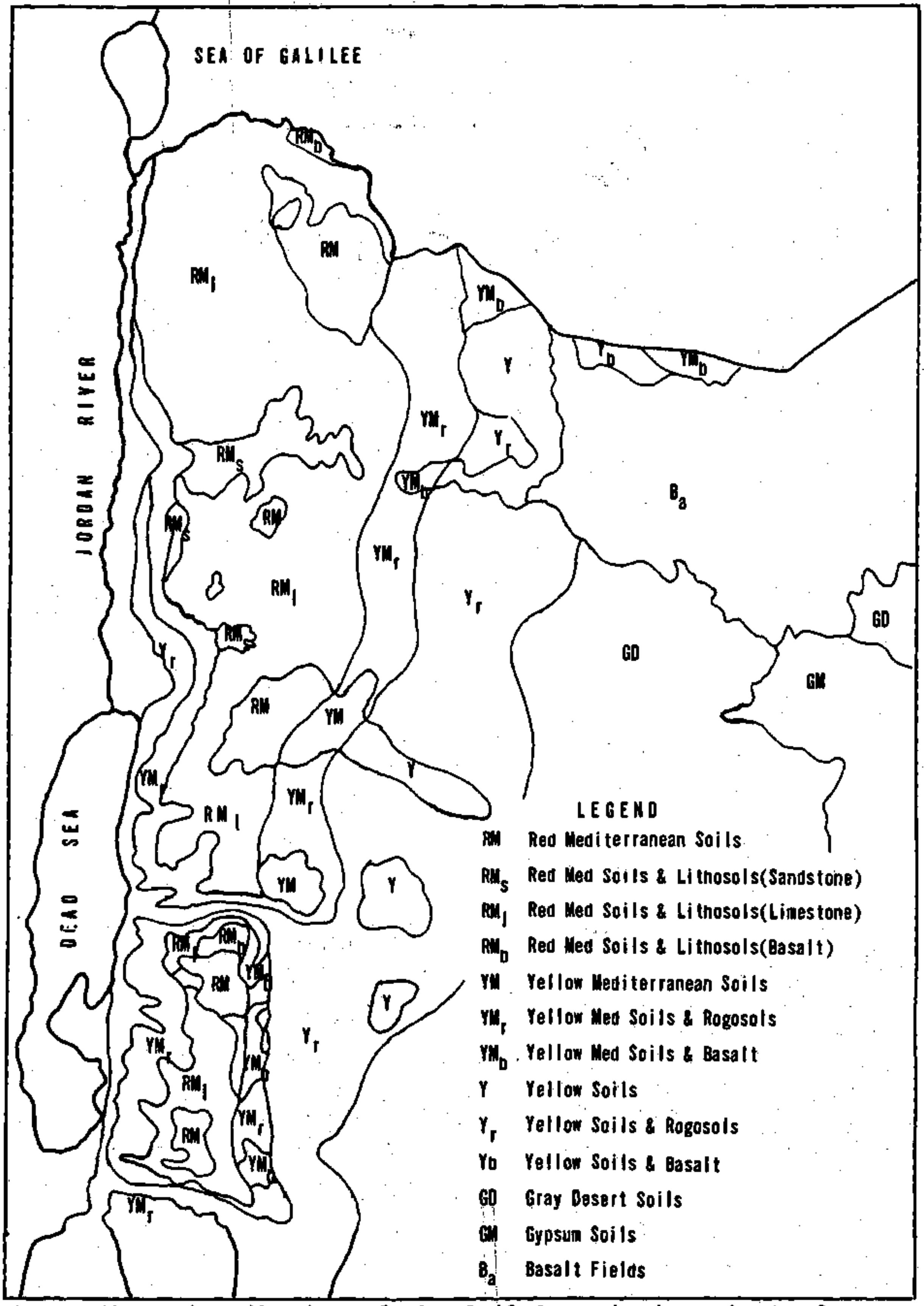


Figure 3b. Distribution of the Soil Associations in Jordan.

soils group dominates, water infiltrates into the soil and adequate soil moisture is available during the wet season.

2. Red Mediterranean Soils and Lithosols (limestone) Association

This association occupies a major part of the high rainfall zone of east Jordan. Lithosols (limestone outcrops with thin soils) cover large surfaces in the soil area. The percentage of Red Mediterranean soils in areas with mountainous relief drops to less than 20 percent, most of which are shallow and overlying bedrock of stoney slopes. Infiltration in these soils is poor because of the steep stoney slopes and the shallowness of the soils. However, in areas of less slopes, Red Mediterranean soils cover as much as 60 percent of the surface. The soil profiles, being more shallow, cannot retain soil moisture and increase the amount of surface runoff. As a result of this, these soils tend to be extremely dry by May or June after the end of the rainy season. Infiltration could occur, however, through the deep soils in the valleys and through the fissured limestone outcrops which are filled with limestone dissolution clay.

3. Red Mediterranean Soils and Lithosols (sandstone) Association

This association occurs in areas where sandstone replaces the limestone. It is mainly found on the lower slopes or in the depressions, namely the depression north of Suwelih and on the slopes of Zerqa River Valley. Red Mediterranean soils occupy only 20 percent of the total area of this association. Soil moisture storage is limited by the shallowness of the soils and the steepness and stoniness of the slopes.

4. Yellow Mediterranean Soils and Regosols Association

The Yellow Mediterranean soils group is located in areas between the Red Mediterranean soils group and the Yellow soils group. This group is, in fact, a transition between the above mentioned two groups. The soil thickness varies from 10 to 35 cm. The texture is silty loam on the surface and silty clay loam at the bottom. The most important characteristic of the top horizon and of the underlying horizon is its hard consistency and the high calcium carbonate content throughout the soil.

Regosols are soils formed on unconsolidated soil material in which no profile development has taken place. The unconsolidated soil materials are chalk in humid areas, sand, and gypsum in the dryer areas.

In this association Yellow Mediterranean soils occupy a relatively large surface with deep profiles occurring both in the valleys and on some of the larger plateaus. Most of the shallow soils, however, are located on slope colluvium. Small areas occur on the moderately steep slopes. Soil moisture storage is limited in the steeply sloping regosolic soils and in shallow soils. The runoff from these slopes infiltrates into the adjacent deep valley-bottom soils.

5. Yellow Mediterranean Soils and Basalt Association

The dominating soils of this association are Yellow Mediterranean soils on weathered basalt. Medium deep and deep soils are found on flatter relief, but soils on the slopes are shallow and covered with many basalt boulders. Part of this soil area is situated in the Wadi Dhuleil between Zerqa and Mafraq. This area is partly filled up by a lava flow.

6. Yellow Soils Association

The Yellow soils group covers about 90 percent of this association's area. It is deep, flat and very homogeneous. Small areas are occupied by alluvial soils and lithosols (basalt and limestone). The texture is silty clay loam. The consistency of the soil material in the A and B horizons is always friable. The consistency of the material in the C horizon is somewhat firmer than in the overlying horizons. The general characteristic of the Yellow soils, in the zones where the vegetation is overgrazed, is the compactness and the imperviousness of the surface layer. A hard crust is formed on the surface of the soil and therefore infiltration through the top layer is very low. Water is therefore lost by surface runoff.

7. Yellow Soils and Regosols Association

This association separates the Mediterranean soils and the Grey Desert soils in the east and the Jordan Valley soils complex in the west. The surface occupied by the Yellow soils is quite important agriculturally. The deep thickness of these soils is found on larger plateaus and in the valleys. Shallow soils occur on slopes.

When basalt prevail, this association is then called Yellow soils and Basalt Association. Shallow phases have been found on slopes where an increase in the number of basalt boulders can be noticed. As a general rule, profiles with a dense cover of basalt boulders are shallow. Usually the depth of the Yellow soils profiles increases with the decreasing of the number of boulders on the surface.

8. The Basalt Field Association

The basalt fields soils occupy large areas in the north-east region. The main characteristic of this association is its boulder-covered appearance. Under the boulder cover, a remarkable depth of unconsolidated material (weathered basalt) is usually found. In some areas, reddish-colored, clayey profiles are found. Moorman stated that the soil association map is general and should be considered as tentative. A more detailed soil survey for the country is badly needed at the present time. However, investigations were completed recently by FAO to prepare soil survey reports for small areas where potential irrigation projects are planned.[22] Such reports are available only for the FAO personnel.

Climate

The Mediterranean Sea is largely responsible in establishing and defining the type of climate in Jordan. Air masses and currents, blowing generally from a westerly direction between October and May, create what is customarily known by "Mediterranean" climate. It is modified by the influence of the eastern desert and characterized by winter rainfall and summer drought.[10] Therefore, there are only two pronounced seasons in Jordan, winter, mild and rainy, and summer, hot and dry.

Geographically there are three climate zones which can be distinguished.

1. The West Bank Highlands
2. The Jordan Valley (Rift Valley)
3. The Eastern Plateau

The main factor causing rainfall is the westerly winds bearing moist air from the Mediterranean Sea, more so in the north of the country than in the southern region. Under the orographic effect, moist air climbs over the West Bank Hills and loses some humidity; then it passes over the Rift Valley where small amounts of rainfall occurs and climbs again over the East Jordan Highlands where some precipitation occurs, but in a lesser amount. Moisture is then exhausted, going eastward, and very small amounts of rainfall. The southern region is drier and receives smaller amounts of rainfall as a result of the prevailing winds which reach the south coming from across north Africa, passing over Sinai Desert, and carrying little moisture. It is worthwhile to mention a particular phenomenon that occurs in this area. Hot dry air blows from the east mostly in spring. This wind is often accompanied by clouds of dust and is called "Khamaseen."

As previously discussed, the Rift Valley acts as a divide for physiographic regions. It also acts as a divide for the climate, namely rainfall and temperature distribution. The average annual maximum temperature falls down moving from the Mediterranean to the western hills and then climbs up into the Rift Valley where it falls down slightly towards the Eastern Plateau. Temperatures are at their lowest in January and February, rising to a peak in August and September. The mean annual temperature in the western plateau is in the vicinity of 100 degrees F and the minimum temperature is 31 degrees F. Passing over the hills into the Rift Valley, the two temperatures are very much higher and averaging 112 and 39. Finally, on the eastern plateau, the average annual maximum and minimum are 104 and 29, respectively. The relative humidity in the eastern plateau varies from about 75 percent in winter to 35 percent in summer. Moving from west to east, there is a general lowering of the average relative humidity.

Rainfall is in the main form of precipitation. Snow falls occasionally and is more pronounced on top of the mountains in the northern region of the country. Dew is very rare and will not be effective enough to play an important role in recharging ground water aquifers.[16]

Evaporation is very excessive. Estimated potential free surface water evaporation, everywhere in excess of rainfall, varies from a minimum of about 1400 mm annually in parts of the west highlands to 2400 mm annually in the southern region.[5] Although potential evaporation is greatly in excess of rainfall on an annual basis, the occurrence of rainfall in the season of low evaporation makes possible not only dry land farming but also considerable ground water recharge in the highland regions.

Rainfall Characteristics and Patterns

There is no fixed pattern in which rainfall can be explained. Rainfall is extremely variable in amount. The most striking feature of the variability is the season-to-season variability in the timing of precipitation. Even during the rainy season, rainfall amounts are higher variable on a month-to-month and year-to-year basis. Long period averages can be quite misleading.

Mean annual rainfall in Jordan varies from over 600 mm in the West Bank and the northern section of the Eastern Highlands to less than 50 mm in the eastern and southern deserts. It is estimated that only about 12 percent of the country's area receives an annual average rainfall exceeding 200 mm and only 6 percent receives over 300 mm rainfall.[17] Table 2 shows annual and monthly variation of rainfall over the ten-year period from water year of 1953 to water year of 1962, as represented by the averages for all recording stations. It should be noted, however, that most of the recording stations

Table 2. Average Seasonal Rainfall in Recording Station (mm).

Water Year	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	Average
No. of Stations	122	138	131	128	135	128	128	134	148	216	
October	4	6	6	2	11	3	0	0	3	5	4
November	117	44	118	16	38	7	17	56	21	0	43
December	88	106	99	79	97	19	10	28	171	49	75
January	60	14	97	95	137	77	67	103	72	32	75
February	115	24	23	94	12	133	14	119	67	72	67
March	21	42	81	101	6	49	74	20	2	27	42
April	34	13	20	22	12	7	10	30	16	16	18
May	1	4	4	18	8	5	1	8	2	12	6
TOTAL	440	253	448	427	321	300	193	364	354	213	330

are located in the western plateau and the northeastern highlands where rainfall exceeds by far in areas south of Jordan and the eastern desert. Although Table 2 does not give any indication about any geographical distribution as a while, it does show obvious indications about the extreme seasonal and monthly variability of rainfall. For example, total monthly rainfall in November for two consecutive 1958 and 1959 water years, are 133 mm and 14 mm, respectively. Also, throughout the rainy season of 1956 water year for example, variability of monthly total rainfall of 137 mm in January and minimum rainfall of 6 mm in March. Many other examples demonstrating the striking behavior of rainfall can be extracted from Table 2. Rainfall intensities are not as high as in some countries of the world. In the wettest area, intensities of 90 mm per hour for 10 minutes, 40 mm in one hour, and 100 mm in one day are not often exceeded at any station.

It is obvious that rainfall is inconsistent, as thus must be the total water balance at locations where the incoming moisture is so undependable in amount and timing. The variability of rainfall is highly significant for agriculture, particularly over large areas of cultivated land where the average rainfall is barely sufficient for dry farming. The timing of rainfall is also of great importance. Poor rains during the period of active growth (February/March to April/May) will result in a poor crop, even if the total rainfall for the year is good. Therefore, the unpredictable pattern of rainfall emphasizes the need for developing the best possible water resources for irrigation by means of diversions and storage reservoirs.

Streamflow Characteristics

Surface flow is separated into flood flow, base flow and spring flow. Base flow is the dominating flow during the summer season specially in perennial wadis whose channel beds intersect the water-bearing formations. Wadis where flow is not continuous form non-perennial wadis. In these wadis flood runoff occurs only during winter seasons and follows the rainfall sequence or pattern. Flood runoff occurs four or five times a year and continuous only for several days after the rainfall events. Therefore, the distinction between flood flow (immediate surface runoff) and base flow is usually sharp. The base flow exhibits an exponential recession during the dry summer period from April through September and increases almost uniformly from a few days after the effective rain of the season, usually October or November, to a maximum value at the end of the winter usually in March.

The separation of base flow from spring flow is not too clear. Even though both types of flow are derived from ground water storage, the criterion for base flow is that the water emerges in a channel which also carries flood runoff. This separation is justified since base flow in a wadis can only be measured by a current meter whereas spring flow in most cases is stationary and measured by volume. In some cases, springs may feed a well defined channel of a small wadi causing such wadi to flow continuously throughout the year.

Based on the above flow separation criteria, Wadis in the East Highlands can be classified into four types.

1. Perennial wadis which flow in winter as a result of rain and in the summer in the form of base flow where ground water storage is intersected by the channel. Here base flow shows a pronounced depletion during the dry months. Seil Zerqa, a tributary to Zerqa River, is a typical example.
2. Non-perennial wadis where only flood flow is the principal flow during the winter season. No contribution from ground water storage to the flow, either because ground water level is too deep or channel cross sections of the wadi is too flat to intersect ground water level. Percolation occurs to recharge the deep ground water storage.
3. Wadis which have an almost constant flow throughout the year, both in winter and in summer. The moderate intensity of rainfall and the pervious nature of the limestone and chalk hills tend to distribute the flood flows, during the wet season, over longer periods of time. In addition, subsurface flow from the outside limit of the drainage area of the wadi contributes to the flow of such wadi.

In other words, the subdrainage area is larger than the surface area of the watershed. This is evident particularly in the case of Wadi Jurum where the total annual flow of the Wadi nearly equals the total annual rainfall on the surface drainage area.

4. Small wadis which are fed by springs during the rainy and dry seasons. Base flow as defined previously does not emerge in the channel. Flood flow, however, is very pronounced. Wadi Um Dananeer, a tributary to Zerqa River has this characteristic.

The flood runoff volume in the desert watersheds is, at first sight, surprising. The proportion of the total rainfall occurring as runoff is probably as high or higher in the desert than in the wetter areas. This is true despite the fact that the annual rainfall in the desert is lower than the wetter areas. This phenomenon can be explained by the Karastic conditions over the limestone desert which are not well developed and where surface detention storage is low. In addition, the silty desert soils have a low permeability thus allowing an increase in surface water storage for a period of time until water evaporates.

Water Resources of Jordan and Their Development

Water resources of any country should be developed and used in the best way to fulfill the needs of its people and their prosperity. Conservation and efficient use of Jordan's limited water resources for general development especially agricultural development, is vital and has an important role in achieving both higher and more stable agricultural incomes for the country.

During the past forty five years numerous plans have been elaborated by various agencies and consultants for development of the water resources of the Jordan River system. Due to the space limitation, the reader is referred to the available literature dealing with this subject.[23,24,25,26,27,28,29,30,31]

Unfortunately, Jordan suffers a great deal of rainfall shortage, averaging about 8700 million cubic meters annually.[18] Rainfall is extremely variable from year to year in quantity and time, and it varies between 4200-9400 million cubic meters annually. Ninety one percent of the total east bank area lies within the zone of 50-200 mm per year[19] and therefore practically more than 80 percent of the area of Jordan is considered a desert or semi-desert land.[20] The average total base flow of rivers and perennial wadis is estimated by 416 mcm per year, meanwhile the average total flows of the floods during the rainy season are in the order of 380 mcm per year. The ground water resources presently available is averaging 205 mcm per year.[21] The reason behind the scarcity of surface flow is due to the high evaporation rate. Almost 80 percent of the rainfall is lost in evaporation.[18] Part of the remaining quantity infiltrates in the soil and the other part appears as surface runoff in wadis. In addition, a portion of the infiltration moisture goes back to the atmosphere in areas where soil is shallow or impermeable.

Surface water resources are available from perennial wadis flowing into the Jordan River and the Dead Sea. All wadis are running dry except those wadis which are fed by springs or groundwater (perennial wadis). Runoff (surface flow) occurs only seasonally after major storms. There are numerous springs located on the east and west of the Dead Sea coast. These springs are in general highly saline, and therefore, they have limited usage. Springs located in the desert oasis of Azraq are important water supplies.

The main water resources in Jordan can be summarized as follows:

1. Surface water: comprised of rivers, streams and wadis. There are two major basins which contain all the surface water.

    a. Jordan River basin

    b. Dead Sea basin

The major perennial wadis in each basin which drain the eastern Jordan highlands and eastern plateau are listed below in conjunction with their respective average annual discharge. (See Figure 4.) It is worthwhile to note that there are numerous non-perennial wadis which carry flood flows after major storms in the rainy season. Table 3 shows Jordan River and Dead Sea basin tributaries.[19]

2. Springs

Springs are considered important water resources in

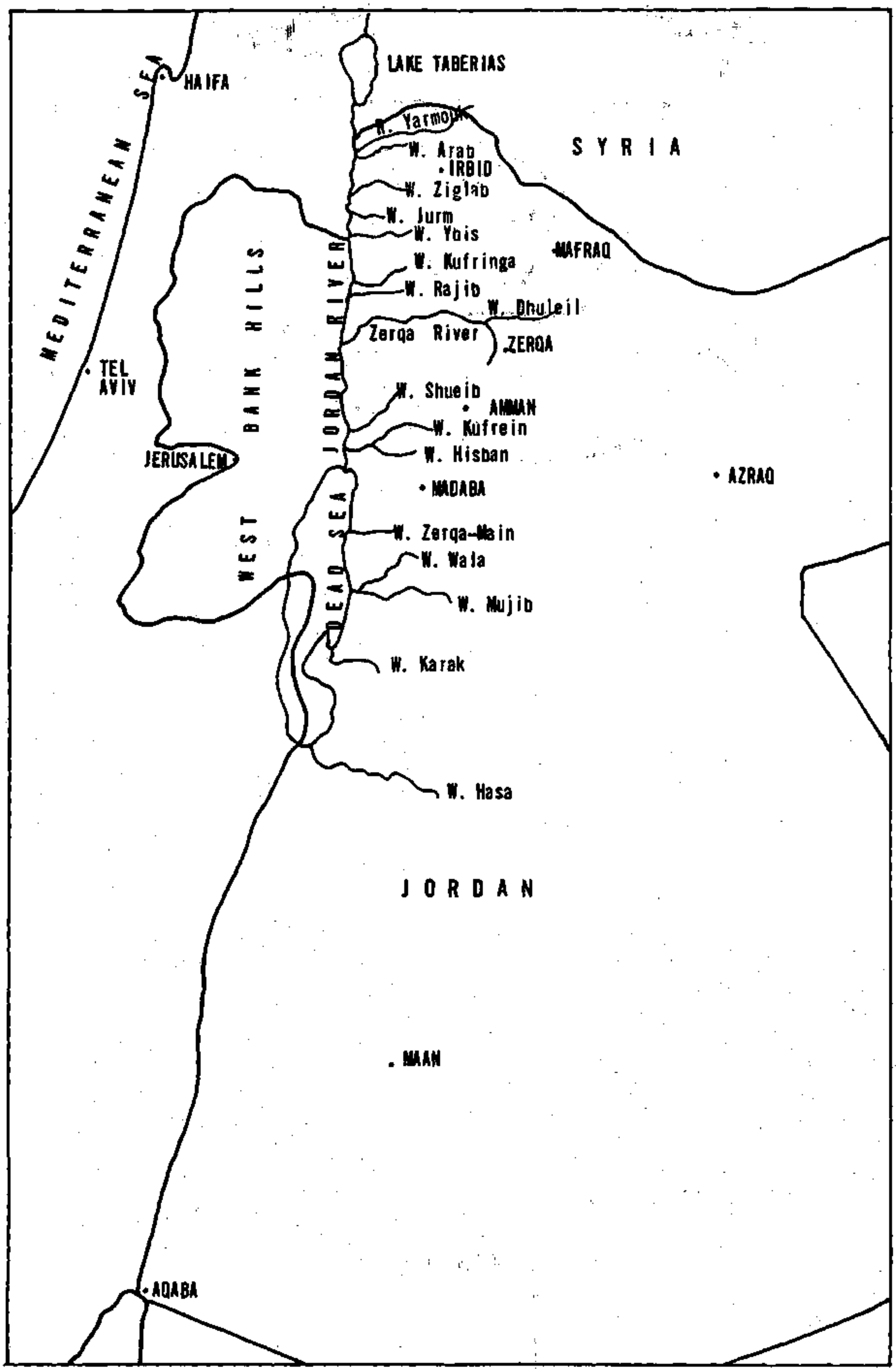


Figure 4. East Bank Surface Water Resources Map.

Table 3. Jordan River and Dead Sea Tributaries and Their Average Annual Flow.

Tributary Name	Avg. Annual Discharge in mcm	
	Base Flow	Flood Flow
Yarmouk (Adasiyah)	200	250
Zerqa (Deir Alla)	38	47
Wadi Arab (N. Shuna)	34	2
Wadi Ziglab	11	2
Wadi Yabis	3.9	1.8
Wadi Kufrinja	5.7	6.8
Wadi Rafjib	2.9	1.1
Wadi Jurm	12.0	.16
Wadi Shueib	8.8	2.0
Wadi Kufrein	10.2	2.0
Wadi Hisban	5.4	0.3
Wadi Zerqa - Main	15	5
Wadi Wala	5	20
Wadi Mujib	40	30
Wadi Hasa	25	5

Jordan for water supplies used for irrigation and domestic consumption. A detailed inventory was carried out in 1965.[3] Most of these springs are periodically measured by the Natural Resources Authority. The total annual discharge of these springs, with respect to districts are as follows:[19]

District	Average Annual Flow, mcm
Irbid	102
Amman	62
Balqa	38
Karak	46
Maan	7

It should be noted that the total spring flow is included within the base flow discharge of the rivers and wadis mentioned earlier.

3. Ground Water Resources

Ground water in Jordan is an important resource. In some areas it comprises more than 87 percent of the total water used. This water is encountered in three types of aquifers:

a. Alluvium and wadi deposits in Jordan Valley and major wadis

b. Fractured Rocks

1) Basalt in north Jordan

2) Chert in middle Jordan

3) Limestone in middle south Jordan

c. Sandstone rock in southern Jordan and in restricted areas in central East Bank.

Table 4 shows the ground water utilized for irrigation purposes only in mcm.[19]

There are other water resource fields in Jordan not listed above either because those fields are very limited or adequate hydrological data is not yet available.

Early in the sixties, the Central Water Authority, presently the Natural Resources Authority, started a program to utilize flood water by constructing earth-fill dams on side wadis at the Jordan Valley and the Eastern Plateau. Some dams have been constructed in the plateau, others like King Talal Dam at Zerqa River are under construction and construction of the Magarin Dam on the Yarmouk has stopped due to the unfortunate events of 1967.

If the construction of proposed dams is to be completed, their capacity will exceed 500 mcm.[19] The study of 14 wadis in the East Bank by consultant engineers has resulted in proposals for building storage dams on seven perennial wadis.[4] All these dams, with the exception of Kufrain and Shueib, would be intended primarily to direct base flow water and flood water to supplement that of the main east Ghor Canal. Table 5 shows completed and proposed dams in the East Bank area.[17,19,20]

Table 4. Groundwater Utilized for Irrigation (in mcm).

Area	Presently Pumped	Expected Quantity That Could be Pumped
Sama-Sdud	4	6
Jarash - Majdal	4	6
Wadi Dhuleil-Halabat	20	24
Azraq	2	8
Amman - Zerqa	12-14	20
Qastel-Jiza	1.2	3
Baga	1.5	4
Jordan Valley		
South Region	32	32
Middle Region (Deir Alla)	2	27
North Region	1.6	1.6
Ghor Mazra - Safi	8.4	10
Wadi Araba	1	3

Table 5. Existing and Proposed Dams in the East Bank.

Existing Dams or Under Construction	Capacity mcm	Use
Kufrain	4.30	Irrigation
Shueib	2.30	Irrigation
Ziglab	4.30	Irrigation
King Talal (Zerqa)	52.00	Irrigation
Um Jimal	1.80	Irrigation
Sultani	1.25	Irrigation & Domestic
Qatrani	4.20	Irrigation & Domestic
Sama Sdud	1.70	Irrigation & Domestic
Proposed Dams		
Magarin and Khalid (Yarmouk River)	400	Irrigation
Wadi Arab	20	Irrigation
Hasa	12	Irrigation
W. Wala	30	Irrigation
Mujib	50	Irrigation

CHAPTER III

MODEL DEVELOPMENT

Many watershed streamflow simulation models have been developed and utilized in the U.S. where emphasis has been placed on the simulation of streamflow of basins located mainly in humid areas. The complexity of these models varies. Some conceptual models[11,34,41,42] are highly complex. Each element of the hydrologic cycle is included. The usefulness of a complex model depends upon the availability and accuracy of the data on meteorological and physical characteristics, the skill of the personnel utilizing the model and the objectives of utilizing the model. The accuracy of streamflow simulation depends upon the estimation of the value of numerous model parameters and the understanding of the various structural elements of such a model.

Some models which have been proposed are more pragmatic than realistic in their formulation of the physical processes which occur within a basin. Other models[37] are simple in their structures and parameters estimation. However, these models sometimes deal with soil moisture accounting and neglect or compromise, for the sake of simplicity, some elements of the hydrologic cycle. They also combine more than one process. They may, however, offer streamflow simulation applicable to their particular use.

The Jordan watershed model, as developed and described in this text, is a conceptual model designed to simulate streamflow in this semi-arid region. The complexity of this model falls between that of the two types of models discussed above. The model is based on a system composed of infiltration, soil moisture storage, drainage, groundwater recharge and evapotranspiration, components which are intended to represent the significant hydrologic processes in a rational manner. It reflects the availability of data on the meteorological and physical characteristics in the region. The model is designed to accept daily rainfall over a basin and daily pan evaporation in the area. Two hydrologic processes included in the model distinguish it from others. First is a component which allows extremely high evaporation rates and the second is a component that allows groundwater recharge and variability of base flow from season to season. Annual potential evaporation in Jordan far exceeds annual rainfall and may, in fact, reach six to seven times the annual rainfall. The base flow recession is essentially flat in the dry period and becomes steeper in the wet season. The different soil characteristics at various depths make it necessary to consider two soil zones, each having its own characteristics. The variability of rainfall patterns makes it necessary to employ a procedure to compute weighted rainfall over a basin. Accordingly, a computer program was developed to read daily rainfall of several stations (maximum of ten stations) and compute the weighted rainfall from the isohyetal maps for each year of simulation. This procedure is described in more detail later in the text.

The model basically consists of six moisture storages:

1. Depression storage
2. Surface runoff storage
3. Upper soil moisture storage, referred to as A Horizon moisture storage
4. Interflow moisture storage
5. Lower soil moisture storage, referred to as B Horizon moisture storage
6. Groundwater storage

Three functions represent the evapotranspiration process in the basin:

1. Evaporation from depression storage
2. Evaporation from A Horizon moisture storage
3. Evaporation from B Horizon moisture storage

Six functions model the following hydrologic processes:

1. Moisture allocation to depression storage
2. Infiltration to A Horizon moisture storage
3. Surface runoff
4. Drainage from A Horizon to B Horizon
5. Recharge from B Horizon to groundwater storage reservoir
6. Base flow recessions

The basic elements of the model are shown in Figure 5. The following is a brief discussion of the model components

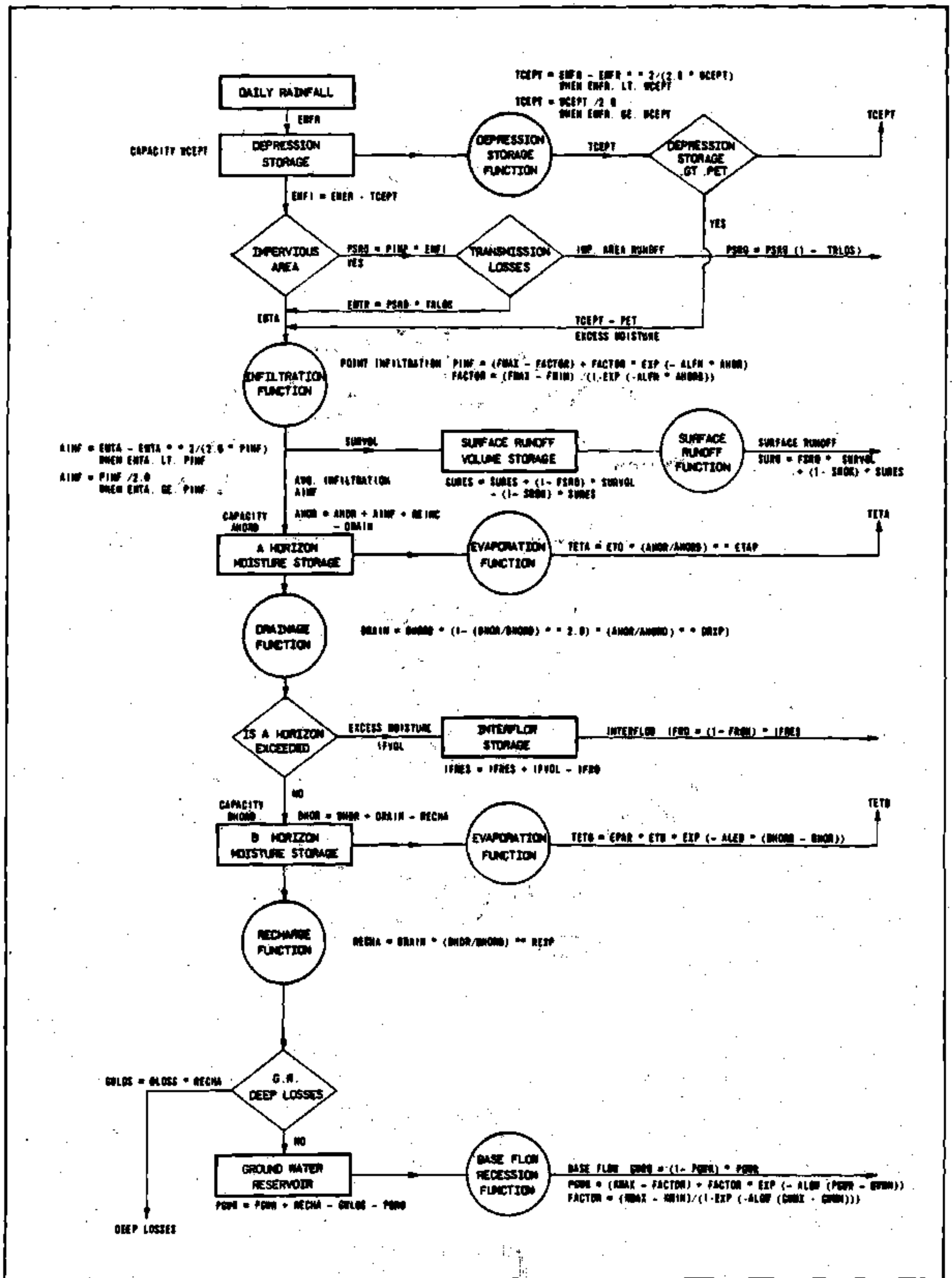


Figure 5. Moisture Accounting Flow Chart of the Jordan Watershed Model.

and the development of their relationships.

Daily Rainfall

The model accepts daily rainfall. The rainfall pattern in Jordan, as previously discussed, makes it necessary to use the weighted rainfall as computed from rainfall stations in the basins. The weighted rainfall over a basin can be computed utilizing the rainfall isohyets. Once the isohyetal map is drawn, several stations can be selected to represent the average value between each isohyet. The weighted rainfall over a basin can then be computed by multiplying each station rainfall by its weight computed from the isohyetal map.

A separate computer program was developed for this purpose. The following steps summarize the procedure:

1. Prepare an isohyetal map for each year of simulation utilizing every rainfall station that has a record for that year (maximum 10-year).
2. For each pair of consecutive isohyets, select one rainfall station to represent the average value (maximum 10-stations).
3. Compute station weights by measuring the areas between each two isohyets.
4. Multiply, for each station, its weight by the daily rainfall and sum for all stations.

Two options were provided in the program. When IPCH = 0, weighted rainfall is computed. Rainfall for each station and the weighted rainfall is printed. When IPCH = 1, the output is weighted rainfall on a punched card deck in a format accepted by the model. The purpose of the first option is to check each station's rainfall record before punching.

Depression Storage

Conventionally, interception in humid regions means that portion of the rain being intercepted by vegetation before reaching the ground surface. In Jordan, vegetation is of low density. Dense woods, if any, are located on the top of mountains. Therefore, a very small amount of rainfall is intercepted by vegetation. Considerable rainfall is trapped in puddles and depressions throughout the basin. Therefore, to account for this moisture, depression storage in this model is treated in a similar procedure to that used for interception storage in other models. The maximum capacity of the depression storage is WCEPT.

Areal variation in topography of land surface influences depression storage capacities. The concept of cumulative frequency distribution of infiltration capacities, developed by Linsley and Crawford, is used to represent the variability in depression capacity. Figure 6 illustrates this concept and its application to depression storage. Daily mositure allocation to depression storage is computed as follows:

$$\mathrm{TCEPT} = \mathrm{EMFR} - \mathrm{EMFR}^2/(2.0 * \mathrm{WCEPT}) \qquad (1)$$

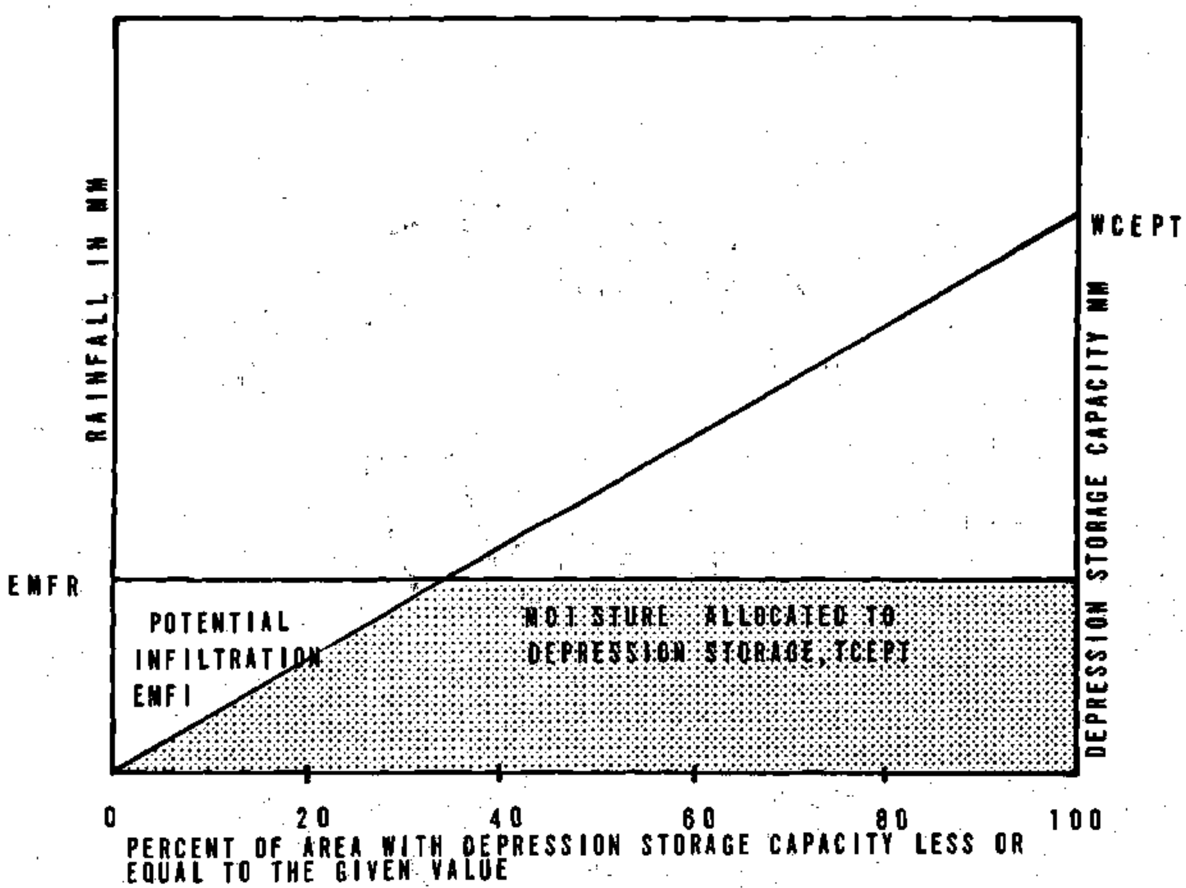


Figure 6. Moisture Allocation to Depression Storage Model.

when rainfall is less than depression storage capacity, and

$$TCEPT = WCEPT/2.0 \tag{2}$$

when rainfall exceeds depression storage capacity.

Excess moisture after moisture allocation to depression storage is

$$EMFI = EMFR - TCEPT \tag{3}$$

where:

TCEPT = computed allocated moisture to depression storage, mm

EMFR = rainfall, mm

WCEPT(*) = maximum depression storage capacity, mm

EMFI = excess moisture after moisture is allocated to depression storage (i.e., potential infiltration), mm

Evaporation from moisture in depression storage occurs at a potential rate. Any moisture remaining in storage, after satisfying evaporation demands, moves downward for potential infiltration. A Horizon and B Horizon moisture storages will be discussed under evapotranspiration.

Runoff From Impervious Areas

Impervious areas normally constitute a small portion of a natural basin. However, in some instances, a considerable portion is mountainous with steep, rocky hills. Runoff from

(*) Denotes a model parameter or a model constant.

these areas is modeled as runoff from impervious areas. Since a large percentage of the flow seeps in to the ground after flowing from the mountains, a parameter, TRLOS, is introduced to account for transmission losses. Runoff from impervious areas is computed as follows:

$$PSRO = EMFI * PIMP\ (1.0 - TRLOS) \tag{4}$$

where

PSRO = runoff from impervious areas, mm

PIMP(*) = fraction of the basin that is impervious

TRLOS(*) = fraction of impervious area flow lost in transition.

Infiltration to A Horizon

Excess moisture from the depression storage and transmission losses are combined to make up the potential infiltration to the upper soil storage. The infiltration process is modeled by an exponential decay function. The maximum infiltration is a function of the moisture available in A Horizon and the physical characteristics of this layer.

Infiltration Model Development

The model in its general form can be written as (refer to Figure 7):

$$PINF = a + b * EXP\ (-ALFN * AHOR) \tag{5}$$

where

PINF = maximum point infiltration, mm/day

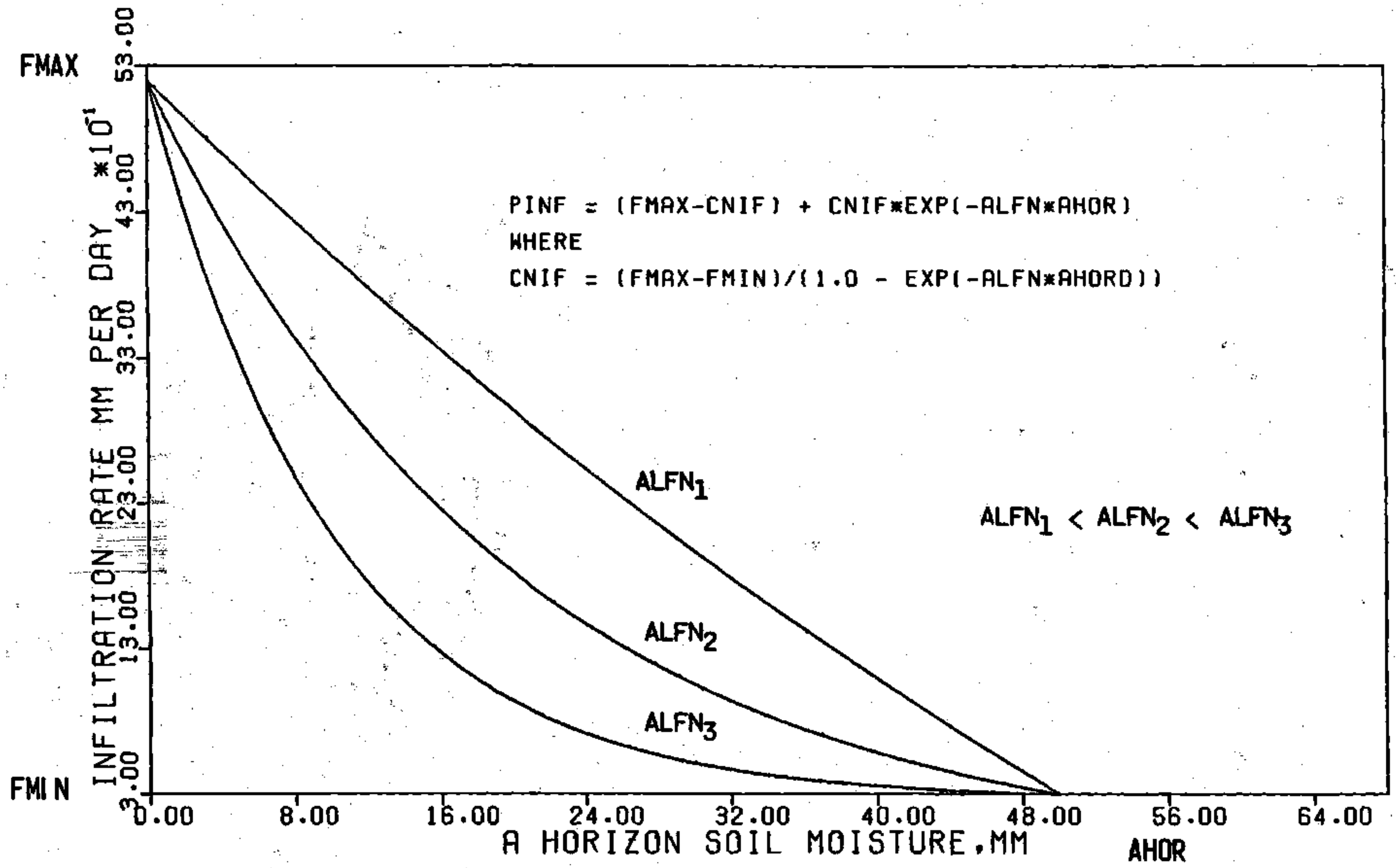


Figure 7. Point Infiltration Rate Model.

a and b = constants

ALFN(*) = decay exponent

AHOR = available soil moisture in A Horizon, mm.

To evaluate the constants of Equation (5), let PINF = FMAX at AHOR = 0 and PINF = FMIN at AHOR = AHORD. Therefore,

$$\text{FMAX} = a + b \tag{6}$$

and

$$\text{FMIN} = a + b * \text{EXP}\ (-\text{ALFN} * \text{AHORD}) \tag{7}$$

where

FMAX(*) = maximum infiltration capacity, mm/day

FMIN(*) = steady state infiltration capacity when AHOR reaches its capacity, mm/day

AHORD(*) = A Horizon soil moisture capacity, mm.

Solving for a and b from Equations (6) and (7) yields

$$a = \text{FMAX} - (\text{FMAX} - \text{FMIN})/(1 - \text{EXP}\ (-\text{ALFN} * \text{AHORD})) \tag{8}$$

$$b = (\text{FMAX} - \text{FMIN})/(1 - \text{EXP}\ (-\text{ALFN} * \text{AHORD})) \tag{9}$$

Substituting the values of a and b in Equation (5) yields

$$\text{PINF} = (\text{FMAX} - \text{CNIF}) + \text{CINF} * \text{EXP}\ (-\text{ALFN} * \text{AHOR}) \tag{10}$$

where

CNIF = constant

= (FMAX - FMIN)/(1 - EXP (-ALFN * AHORD)).

The areal variations of infiltration capacity concept, as presented by Crawford and Linsley, is used to convert point potential infiltration to average infiltration over a basin. It aids the modeling of the surface runoff volume for the smaller, low intensity storms. Let EMTA be the moisture supply to A Horizon as shown in Figure 8. The infiltration, AINF, is computed as follows:

$$\text{AINF} = \text{EMTA} - \text{EMTA}^2/(2.0 * \text{PINF}) \text{ , EMTA} < \text{PINF} \tag{11}$$

and

$$\text{AINF} = \text{PINF}/2.0 \text{ , EMTA} \geq \text{PINF} \tag{12}$$

Equations (11) and (12) attempt to account for the variation in infiltration capacities. It was found that using these equations improved modeling of the surface runoff volumes for smaller storms when compared with the uniform infiltration rate used in an earlier version of the model.

Surface Runoff

Surface runoff volume is the excess moisture that remains after the infiltration process takes place.

It is computed as:

$$\text{SURVOL} = \text{EMTA} - \text{AINF} \tag{13}$$

where:

SURVOL = surface runoff volume, mm.

The surface runoff component of the streamflow is a portion of

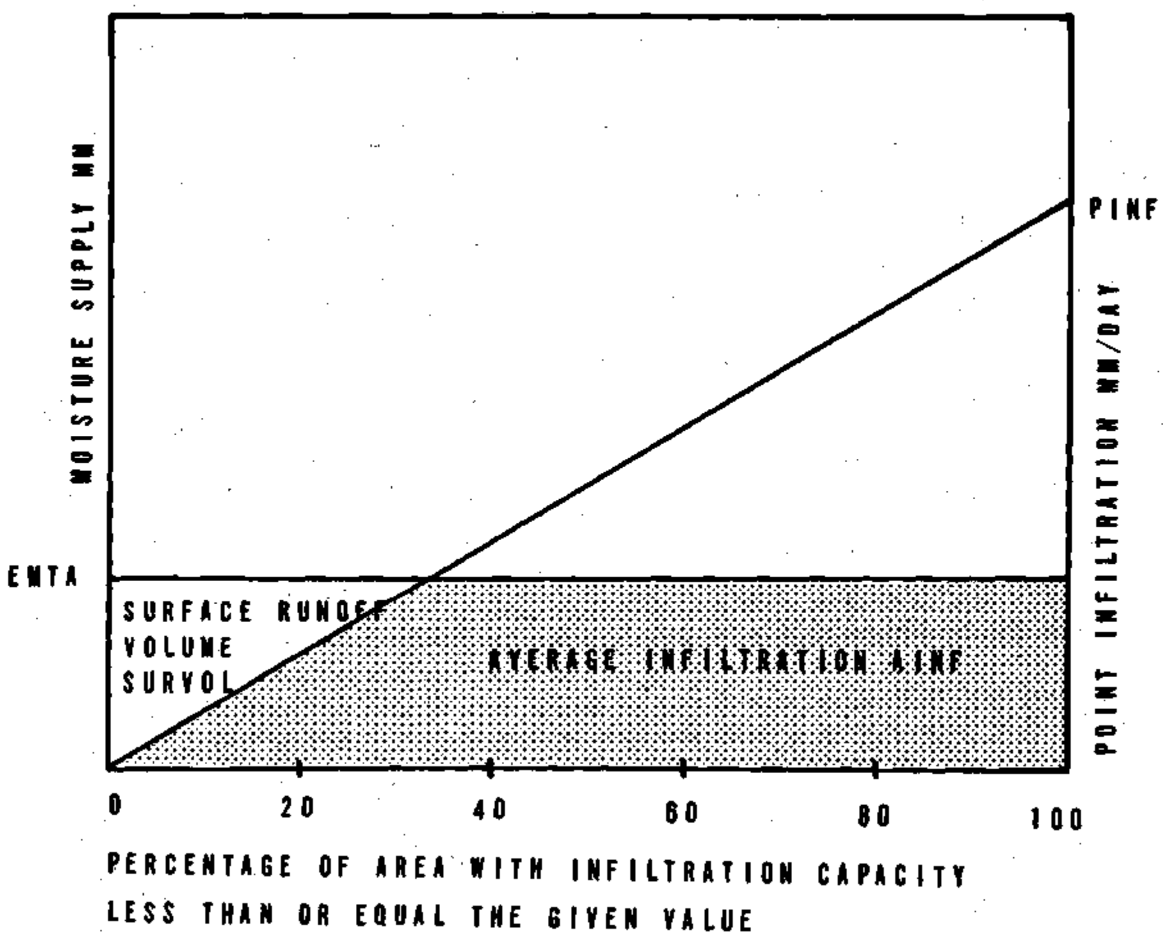


Figure 8. Average Infiltration Rate Model.

this volume. The other portion remains as surface runoff volume storage to be depleted at a specific rate during the following days. The surface runoff process and the surface runoff volume in transit are represented by the following simple models[35,36] as illustrated in Figure 9.

$$SURO_i = FSRO * SURVOL_i + (1.0 - SROK) * SURES_i \tag{14}$$

and

$$SURES_{i+1} = SURES_i + (1.0 - FSRO) * SURVOL_i - (1.0 - SROK) * SURES_i \tag{15}$$

where

$SURO_i$ = routed surface runoff in the ith day, mm/day

FSRO(*) = fraction of surface runoff volume

SROK(*) = surface runoff recession factor

$SURES_i$ = surface runoff volume storage at the beginning of the ith day, mm

$SURES_{i+1}$ = surface runoff volume storage at the end of the ith day, mm.

Equation (14) states that the routed surface runoff that appears at the gage site in the ith day is equal to the portion of the surface runoff volume that is produced in the ith day, as determined by FSRO, plus the routed surface runoff storage. This storage is depleted at a recession rate determined by SROK.

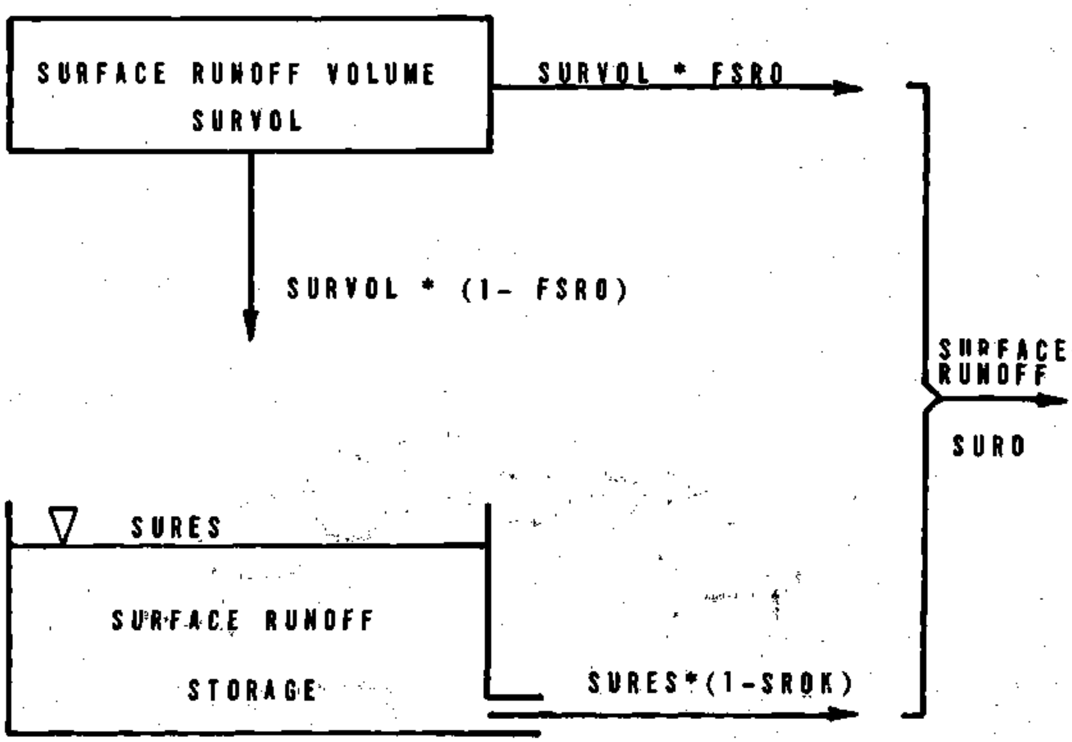


Figure 9. Schematic Diagram of the Surface Runoff Model.

Soil Moisture Storages

Soil moisture storage is divided into two compartments, A Horizon moisture storage and B Horizon moisture storage. The upper soil is shallow and has a limited moisture capacity. The soil in its total depth is not homogeneous and does not have uniform characteristics. In the long dry period, the upper soil forms a hard layer known as a pan. The lower soil, while sealed by the upper dry soil, continues to be affected by the evaporation process at a very reduced rate. Evaporation proceeds at different rates from the upper soil moisture storage and from the lower soil moisture storage. Infiltration and interflow processes take place in the upper soil. Drainage from the upper soil to the lower soil takes place at a rate determined by the permeability of the lower soil. Finally, groundwater recharge takes place when moisture is transferred from the lower soil to the groundwater reservoir. Therefore, the vertical differences in soil characteristics make it necessary to divide the soil moisture into two different storages, namely, the A Horizon moisture storage and the B Horizon moisture storage. The initial soil moisture in A Horizon is set to zero due to the dryness of the top soil at the beginning of the water year. Meanwhile, a model constant, BSMI(*), represents the initial soil moisture in B Horizon.

Drainage

The process by which moisture moves downward from A

Horizon to B Horizon is called drainage. The amount of moisture to be drained is controlled by the maximum drainage capacity, the amount of moisture in A Horizon, and the amount of moisture in B Horizon. The following function, subsequently found to be inadequate, was developed to represent the downward motion of the moisture.

$$\text{DRAIN} = \text{BHORP} * (\text{AHOR}/\text{AHORD})^{\text{DRXP}} \tag{16}$$

where

DRAIN = amount of drainage, mm/day

BHORP(*) = maximum drainage rate, mm/day

AHOR = moisture available in A Horizon moisture storage, mm

AHORD(*) = maximum capacity of A Horizon storage, mm

DRXP = drainage decay exponant.

Equation (16) indicates that with constant BHORP and DRXP, drainage depends on the amount of available moisture in the A Horizon storage. This function was then modified to reflect the amount of moisture in the lower soil. Obviously, the drier the lower soil, the more drainage will occur. Thus, the model was modified to the following final form:

$$\text{DRAIN} = \text{BHORP} * (\text{AHOR}/\text{AHORD})^{\text{DRXP}} * (1-(\text{BHOR}/\text{BHORD}))^{\text{DRXP}} \tag{17}$$

where

BHOR = moisture available in B Horizon storage, mm

BHORD(*) = maximum capacity of B Horizon storage, mm.

As a result of many simulation runs, a value of DRXP = 2.00 was found satisfactory.

Interflow

Interflow or lateral flow is modeled in a simple manner to avoid excess complexity of the model. A moisture accounting is performed on the A Horizon storage. The input to the system is the incoming moisture from infiltration. The output is the outgoing moisture via drainage and evaporation. When A Horizon storage exceeds its capacity, the excess moisture moves laterally as interflow volume to the interflow storage. Interflow is routed daily utilizing a prespecified interflow recession factor. The interflow process is represented by the following two equations.

$$IFRO_i = (1.0 - FROK) * IFRES_i \tag{18}$$

$$IFRES_{i+1} = IFRES_i + IFVOL_i - IFRO_i \tag{19}$$

where

IFRES = interflow reservoir volume, mm

IFVOL = added interflow volume when A Horizon is exceeded, mm/day

IFRO = routed interflow mm/day

FROK(*) = interflow recession factor.

Groundwater Recharge

Recharge occurs from B Horizon moisture storage to feed the groundwater reservoir. The rate of recharge is controlled by the incoming moisture from A Horizon storage and by the amount of moisture already available in B Horizon storage. Some models[40,42] assume that recharge, or percolation to groundwater, occurs only when the ratio of the moisture available in the upper soil to the upper soil capacity is greater than the ratio of the moisture in lower soil to the lower soil capacity. In other models[36,38] the inflow to groundwater is represented as a function of the surface runoff. Although simulation results from these models seem satisfactory, recharge functions are developed on an artificial basis to induce groundwater recharges.

In this model, the moisture, DRAIN, which moves from A Horizon storage to B Horizon storage is considered a potential groundwater recharge. The amount of recharged moisture is governed by the ratio of available moisture in B Horizon to the B Horizon storage capacity. Recharge is computed in the following manner as illustrated in Figure 10.

$$\mathrm{RECHA} = \mathrm{DRAIN} * (\mathrm{BHOR}/\mathrm{BHORD})^{\mathrm{REXP}} \tag{20}$$

where

RECHA = recharged moisture from B Horizon storage to ground water reservoir, mm/day

DRAIN = amount of moisture drained from A Horizon storage to B Horizon storage. It is considered the maximum recharge that could occur, mm/day

REXP(*) = recharge decay exponent.

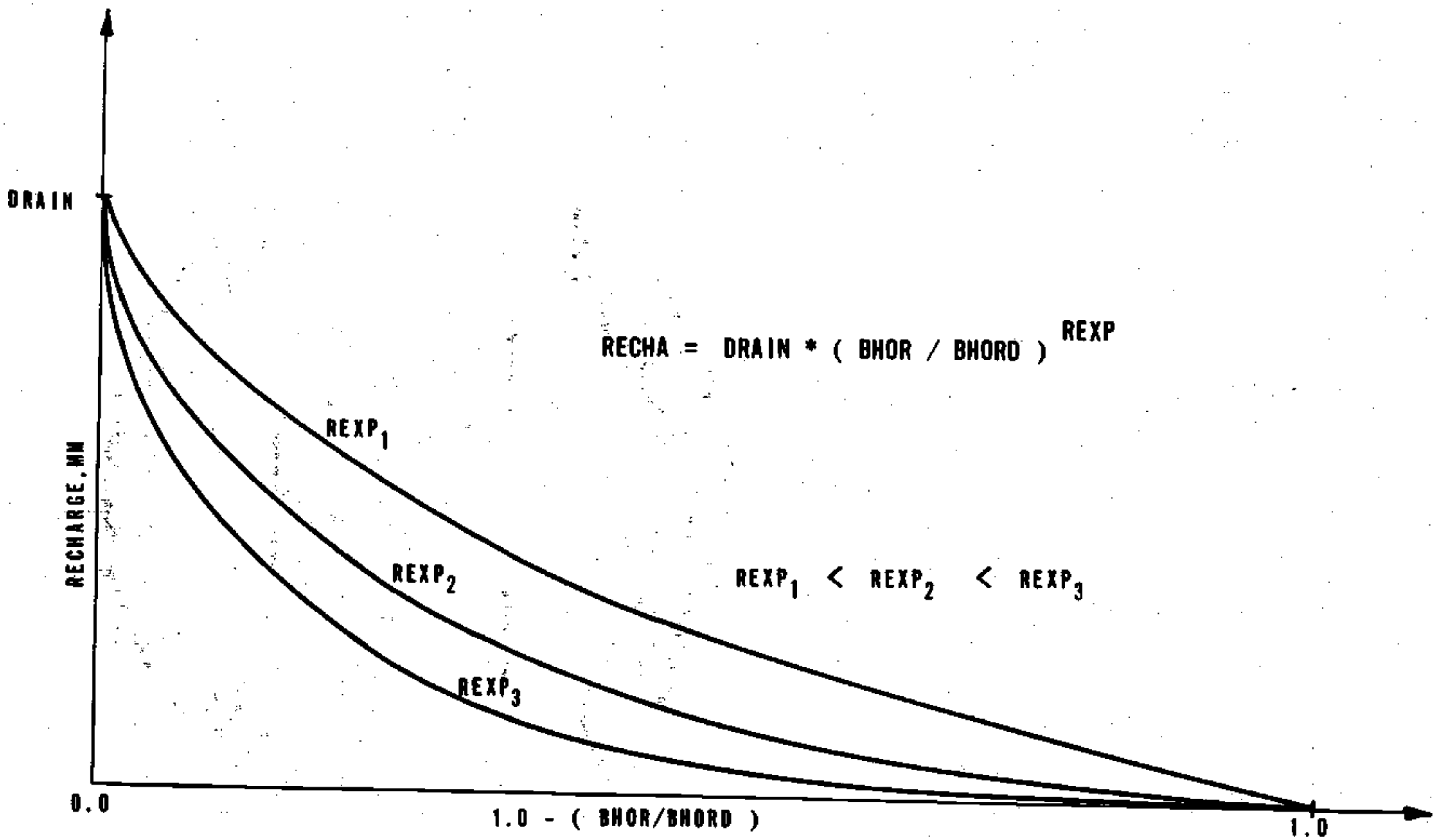


Figure 10. Groundwater Recharge Model.

It was found that the value of REXP is sensitive in determining the recharge and, therefore sensitive, in determining low flows. Therefore, instead of making REXP a fixed value, better low flow simulation results were obtained by considering this exponent as an input parameter subject to changes from basin to basin.

The geological formations in a semi-arid region such as Jordan plays an important role in determining the low flows which appear in the channel. A portion of the recharged water finds its way to deep aquifers, i.e., it is lost from the channel flow. In addition, many springs and seeps are located in the basins. The majority of flows from these sources are fully utilized as a water supply by various communities in the area. It would be difficult to try to model these losses as they are impossible to determine quantitatively. The approach adopted here was to assume that a portion of the recharged moisture is lost through utilization of spring water and by percolation to deep aquifers. The following simple model represents the groundwater loss.

$$GWLOS = DLOSS * RECHA \tag{21}$$

where

GWLOS = lost moisture to deep aquifers and through springs and seeps, mm

DLOSS(*) = a lumped parameter to represent the portion of recharge being lost.

Groundwater Reservoir

Perennial wadis are those wadis which are flowing continuously all year. If the channel bed of a wadi intersects the water table, water from the groundwater reservoir flows into the wadi as base flow in the channel and forms a perennial wadi. The modeler visualizes this water table as the top of the groundwater reservoir. The level of the reservoir fluctuates according to the amount of recharge from the upper soils. The recession curves during a storm or during a dry period vary accordingly. Observation of recorded streamflow data of perennial wadis indicates that base flow has variable recession curves. Slopes are nearly flat during dry periods. Steeper recession curves are observed during and shortly after the wet periods of the year. There is a gradual transition of recession curve slopes, in streamflow verses time semi-log plots, depending on the level of the water table and as a consequence of groundwater storage. The smaller the groundwater storage the flatter the recession curve. Thus the status of the groundwater reservoir determines the value of the base flow recession constant. In order to model base flow, it is therefore necessary to establish a relationship between the base flow recession constant and groundwater storage. Let KMAX(*) represent the maximum recession constant which corresponds to the minimum groundwater storage, QMIN, during dry periods. Also let KMIN(*) represent the minimum recession constant which corresponds to the maximum groundwater storage, QMAX, during wet periods. The desired relationship between base flow recession constant, PGWK, and groundwater storage, PGWR, is developed as follows (refer to Figure 11):

The model in its general form can be written as:

$$PGWK = a + b\ e^{-ALGW*(PGWR-QMIN)} \tag{22}$$

Let q = PGWR - QMIN

Therefore

$$PGWK = a + b\ e^{-ALGW*q} \tag{23}$$

Evaluate Equation (23) at PGWR = QMIN (i.e., q = 0). Therefore,

$$KMAX = a + b \tag{24}$$

Evaluate Equation (23) at PGWR = QMAX (i.e., q = QMAX - QMIN). Therefore,

$$KMIN = a + b\ e^{-ALGW(QMAX-QMIN)} \tag{25}$$

Solving for a and b from Equations (24) and (25) yields

$$a = KMAX - (KMAX - KMIN)/(1 - e^{-ALGW(QMAX-QMIN)}) \tag{26}$$

$$b = (KMAX - KMIN)/(1 - e^{-ALGW(QMAX-QMIN)}) \tag{27}$$

Substitute the value of a and b in Equation (23)

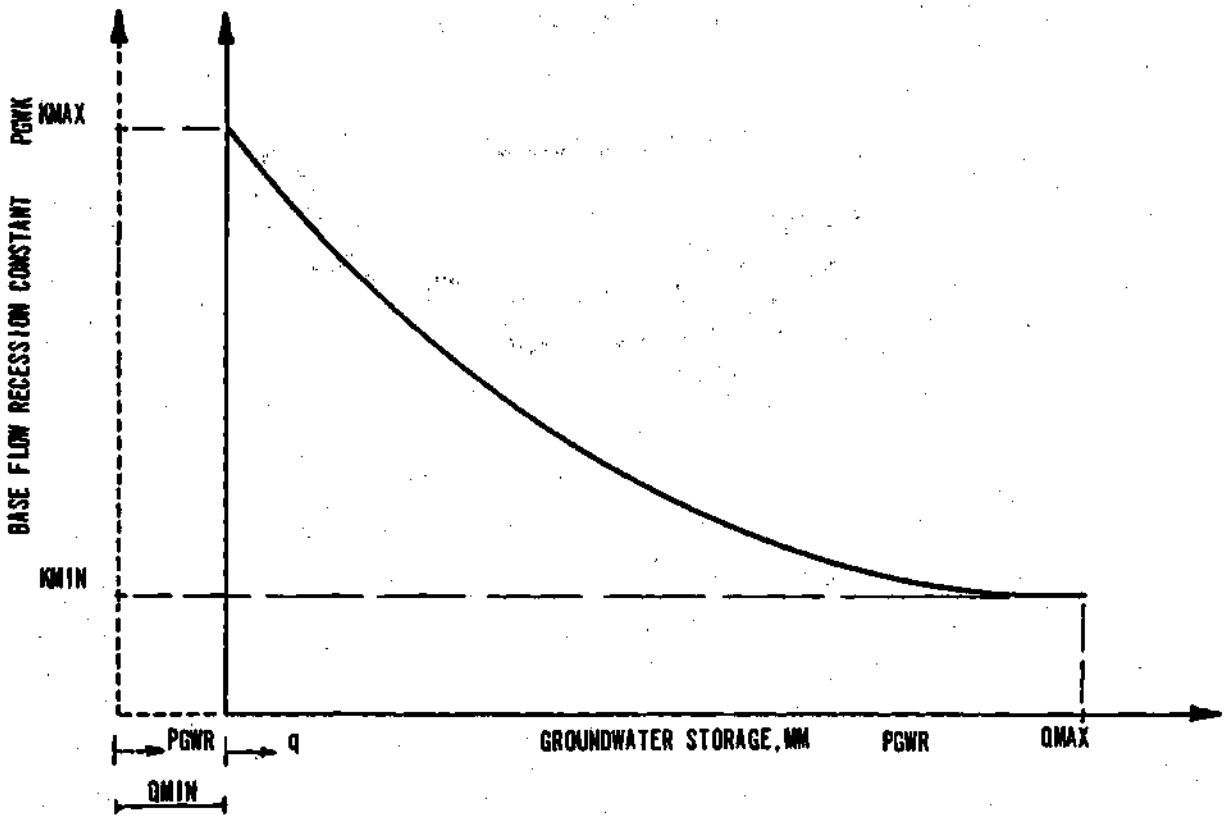


Figure 11. Base Flow Recession Constant Model

$$PGWK = (KMAX - EXPON) + EXPON * e^{-ALGW(PGWR-QMIN)} \tag{28}$$

where

EXPON = constant

$$= (KMAX - KMIN)/(1 - e^{-ALGW(QMAX-QMIN)}) \tag{29}$$

ALGW = function decay exponent

The value of ALGW, QMAX, and QMIN are fixed based on the model calibration. ALGW, with a value of 0.05, QMAX, with a value of 50.00 mm, and QMIN, with a value equal to the initial groundwater storage, BGWR(*), gave satisfactory results. These values were selected based on calibrations of the two available watersheds. If the groundwater storage value falls below the preassigned minimum value, the corresponding recession constant approaches a maximum value of 1.0 as illustrated in Figure 12.

Once groundwater storage is determined each day, the base flow recession constant can be computed using Equation (28). Groundwater storage is then routed each day to compute the daily base flow as follows:

1. Compute present groundwater storage

$$PGWR_{i+1} = PGWR_i + RECHA_i - GWLOS_i - PGRO_i \tag{30}$$

2. Compute base flow recession constant, PGWK which corresponds to PGWR in Equation (28).
3. Compute base flow, PGRO using above information.

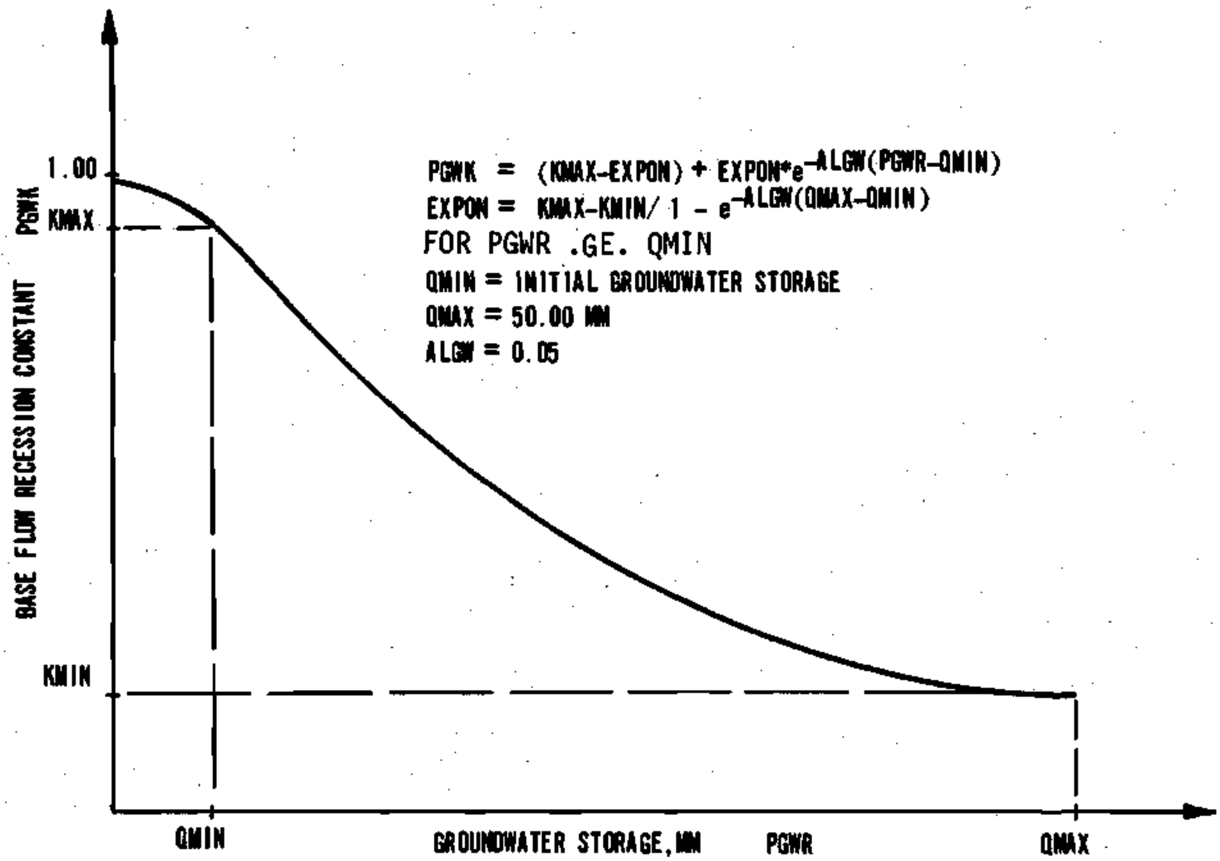


Figure 12. Final Form of the Base Flow Recession Constant Model.

$$PGRO_i = (1.0 - PGWK) * PGWR_i \tag{31}$$

Modeling base flow in the form of Equation (31) with PGWK as a constant did not yield satisfactory results over the wide range of PGWR experienced in the Jordan watersheds. It was found that allowing PGWK to vary as shown in Figure 12 improved the simulation significantly. The computed base flow is added to other runoff components giving total simulated runoff.

Evapotranspiration

In order to make an estimate of potential evaporation from free surface water, daily pan evaporation measurements are used. It was found that the average monthly temperatures near Fresno, California closely approximated those in Amman.[12] Pan coefficients which are used in the model were assumed to be the same coefficients used in the Fresno area. These are listed as follows:

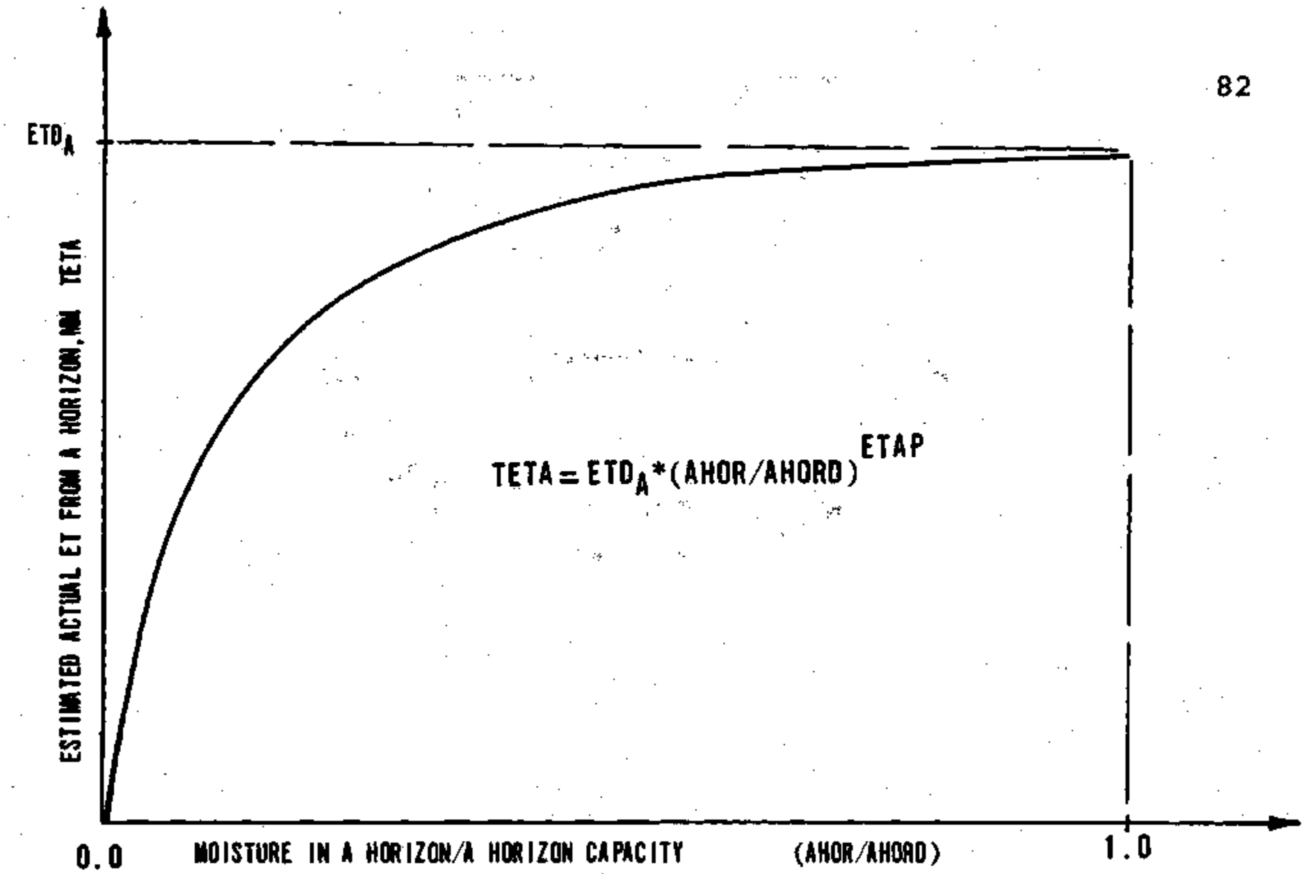
O	N	D	J	F	M	A	M	J	J	A	S
.75	.70	.65	.60	.55	.60	.65	.75	.80	.85	.85	.80

The estimated potential evaporation was obtained by multiplying the daily pan evaporation measurement by the monthly pan coefficients.

In spite of errors which may be introduced from pan evaporation measurements, this method provides a simple means of evaporation estimation. In order to use other methods, such as the Penman equation, climatical and meteorological data are required. The poor coverage of the necessary climatic data at the present time favors pan evaporation measurements.

In a semi-arid country, such as Jordan, the importance of the availability of water must be stressed. In the early stages of the rainy period each year, when there is no soil moisture available, the amount of evaporation is determined by the amount of rainfall. The presence of a layer of dried soil between the energy source (atmosphere) and the lower soil layer containing moisture provides some resistance to evaporation and reduces its rate and amount. Evaporation from a drying soil is a characteristic of the Jordan hydrologic cycle from April through November or December each year.

The evaporation process takes place in three moisture storages, namely, depression storage, A Horizon moisture storage, and B Horizon moisture storage. Moisture in depression storage evaporates at a potential rate. Evaporation from the upper soil occurs if there is available moisture to satisfy part or all of the potential evaporation. During the rainy months where precipitation exceeds evaporation, soil will gradually become fully covered by natural vegetation and crops. Potential evaporation demand during this period is met from the available moisture in A Horizon. Evaporation rates become progressively more dependent on water stored in the soil. The evaporation rates remain at nearly potential rates until the available water storage of the top soil, within the root



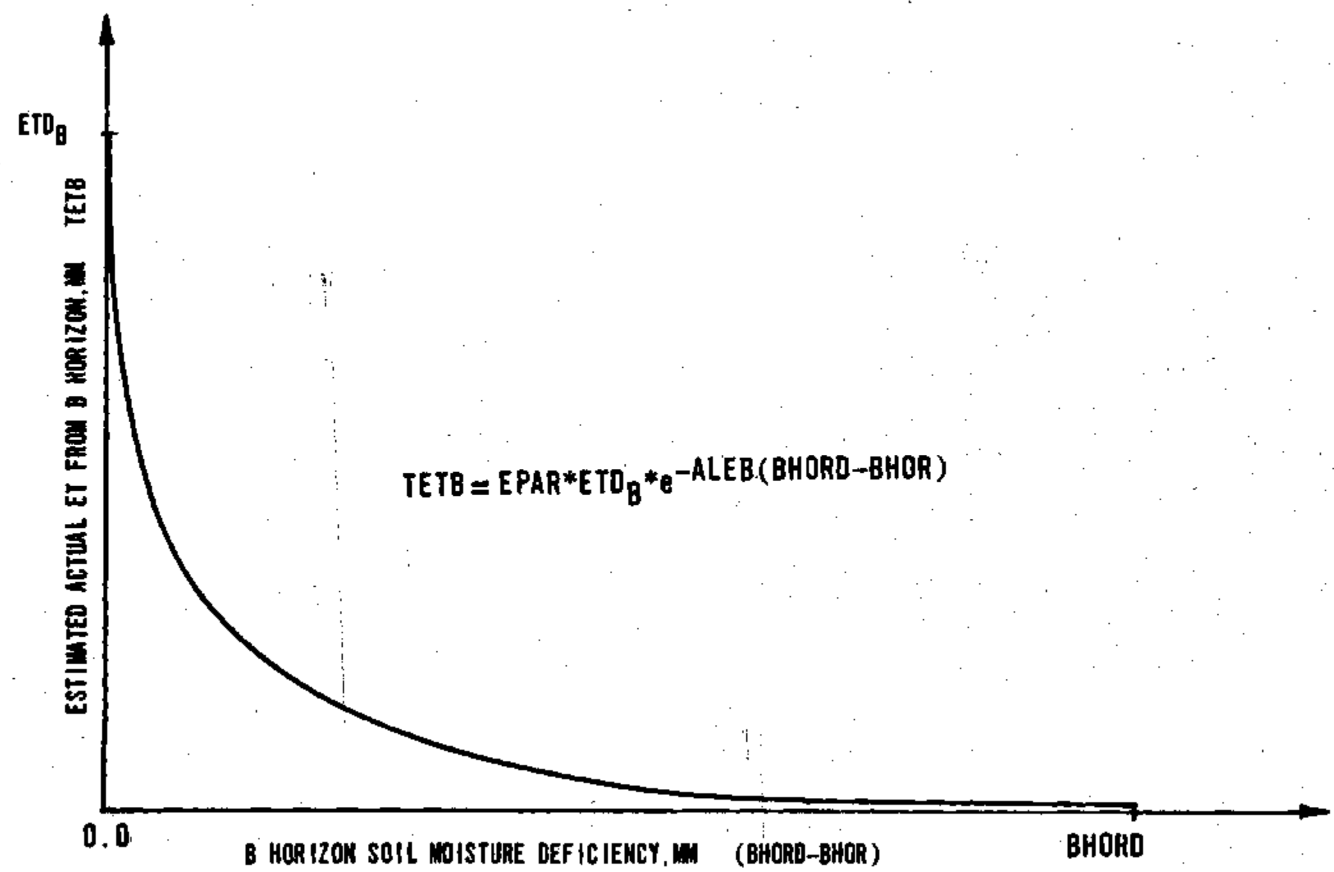


Figure 13. A Horizon and B Horizon Evaporation Models.

zone, is nearly depleted. At this point, as the resistance to water movement through the soil to the root surface increases, the evaporation rate falls rapidly. At this stage the layer of the soil within the root zone will be a layer of essentially dry material. This dry layer serves as a barrier to evaporation of the soil moisture available in the layer of soil below the root zone, i.e., the B Horizon.

Evaporation from A Horizon is modeled according to the following function as shown in Figure 13.

$$TETA = ETD_A * (AHOR/AHORD)^{ETAP} \quad (32)$$

where

TETA = simulated evapotranspiration from A Horizon moisture storage, mm/day

ETD_A = unmet potential evaporation, mm (i.e., potential evaporation minus evaporation from depression storage)

ETAP = function exponent.

A value of 0.075 was selected for ETAP as results of many simulation runs.

Evaporation from the lower zone soil takes place at a reduced rate for reasons previously mentioned. That is not the case in humid areas where deeply rooted trees penetrate the soil and consume moisture by transpiration. Evaporation from B Horizon, TETB, can be computed by the following equation (refer to Figure 13).

$$TETB = EPAR * ETD_B * e^{-ALEB(BHORD-BHOR)} \tag{33}$$

where

EPAR(*) = evaporation parameter

ETD_B = unmet potential evaporation, mm (i.e., potential evaporation minus evaporation from depression storage and upper soil storage)

ALEB = evaporation decay exponent.

From many simulation runs, a value of 0.05 was selected for ALEB. The maximum value of EPAR is 1.00. The purpose of this parameter is to give flexibility in estimating the actual evaporation from the soil. The form of Equation (33) indicates the low rate of evaporation during the dry seasons.

The amount of evaporation from groundwater storage in the rainy season depends mainly on the depth of the water table. Many measurements of groundwater loss through evaporation from bare soils have been made in the Western United States, which has similar climatic conditions to Jordan. It has been concluded that rates of evaporation from groundwater becomes extremely low when the water table falls to a depth of more than 120 cm.[43] Therefore, it is assumed in this model that no evaporation will take place from groundwater storage due to the fact that the depth of the water table in most areas far exceeds this value.

Development of each function of the general model and its constants is based on all of the minimal amount of data available and was applied to two watersheds in the semi-arid region of Jordan. Calibration of the model was achieved using the limited available information. Further extensive calibration of the model is necessary if it is put into use by the N.R.A. where more data is available. The N.R.A. is on the verge of establishing a computerized data coding on cards which would save much time in future uses of such a model.[39]

Parameters Estimation, Sensitivity, and Optimization

The criteria used in selecting the parameters to be optimized were based on the degree of difficulty of estimating such parameters. There are 20 input variables required to run the simulation model. Ten parameters were selected to be optimized simultaneously. A list of parameters and constants used in the Jordan watershed model is shown in Table 6. The constants as defined here are those parameters which are not optimized. The value of these constants can be determined from observed runoff data and the physical characteristics of a given basin.

The ten constants can be grouped into two categories. The first category contains constants which can be determined or estimated with some experience. These constants are SQKM, PIMP, TRLOS, WCEPT, BSMI, and BGWR. The constants which fall in the second category are recession - associated constants which may required insight or study of streamflow data. These constants are SROK, FROK, KMIN, and KMAX.

Table 6. List of Constants and Parameters Used in the Jordan Watershed Model.

Constant	Definition
BSMI	Initial soil moisture in B Horizon, mm
BGWR	Initial groundwater reservoir storage, mm
SQKM	Drainage area in square kilometers
WCEPT	Maximum depression storage capacity, mm
FROK	Interflow recession constant
KMIN	Minimum base flow recession constant
KMAX	Maximum base flow recession constant
SROK	Surface runoff recession constant
PIMP	Impervious area fraction of total area
TRLOS	Transmission losses in fraction

Parameter	Definition
FMAX	Maximum point infiltration capacity, mm/day
FMIN	Minimum (steady state) infiltration capacity, mm/day
ALFN	Infiltration function decay exponent
AHORD	Maximum storage capacity of A Horizon, mm
BHORP	Drainage parameter, mm/day
FSRO	Surface runoff volume parameter
REXP	Recharge function decay exponent
BHORD	Maximum storage capacity of B Horizon, mm
EPAR	B Horizon evaporation reduction parameter
DLOSS	Fraction of groundwater recharge lost to deep aquifers and springs

Logarithmic plotting of observed hydrographs aids selecting reasonable values for the recession constants. Streamflow analyses suggest the following values for the recession constants; SROK = .15 - .25, FROK = .30 - .40, KMIN = .975 - .990, and KMAX = .995 - .999. Once the value for KMAX is estimated, a value of BGWR can be estimated. From mean daily discharge data, select a discharge in millimeters at the beginning of the period when the groundwater discharge begins to level out. This discharge divided by the quantity (1 - KMAX) should provide a reasonable estimate for BGWR.

The ten parameters listed in Table 6 are optimized in the model. It would be difficult to estimate these parameters without a great deal of experience. However, data obtained from soil reports can be used to select initial values for most of the optimized parameters. Sensitivity analysis for the optimized parameters provides the user with a means of determining the relative importance of each parameter when the model is calibrated. Sensitivity analysis was performed for each parameter by introducing a ten percent increment to the parameter value. The increase in the objective function value (the sum of the absolute value of the errors), a percentage of the initial value, was computed each run. The following is a summary of the sensitivity analysis results which includes a list of each parameter and the corresponding percent increase in the objective function value (refer to Table 6 for parameter definition):

AHORD	REXP	ALFN	BHORD	DLOSS	FMAX	FSRO	FMIN	BHORP	EPAR
8.02	5.26	4.48	4.19	3.33	2.44	1.04	0.81	0.50	@0.00

The sensitivity of each parameter, as can be seen from the above list, varies. The most sensitive parameters can be divided into two categories. The parameters which govern a sequence of model components fall into the first category. The upper soil moisture storage capacity, AHORD, for an example, controls three model components. These components represent the evaporation from the upper soil moisture storage, the infiltration process, and the moisture drainage from the upper soil storage to the lower soil storage. AHORD, therefore, is the most sensitive parameter. The paramaters which describe the curvature of the model components functions fall into the second category. The recharge function decay exponent, REXP, which governs the groundwater recharge process is an example of this group. REXP is the second most sensitive parameter.

Parameter optimization utilizing the direct search technique was first described as Pattern Search and developed by Hooke and Jeeves[32] and later modified by Munro[33] and Currie and Lumb.[34] The procedure of Pattern Search optimization technique is based on minimizing a selected objective function and obtaining the corresponding parameter values. The first step in parameter optimization is to start with selected initial values. Two types of parameter adjustments are made: local excursion and pattern move. In the initial local excursion, an increment, DELTA, is added to the first parameter value and the objective function is evaluated. The new value of the parameter is accepted if the objective function decreases. The increment, DELTA, varies in direction. Trials are made in the positive and the negative direction, without violating the upper or lower limit, by adding or subtracting DELTA from the parameter value. The best value of the parameter and the direction of incrementing are retained accordingly. If no improvement occurs from incrementing in both directions, the initial value is retained. The same procedure is applied to the next parameter. After the completion of a local excursion maneuver a check is made to decide whether a pattern move, a resolution, or a destroy pattern maneuver will be accomplished next. The following four items illustrate the procedure:

1. A pattern move would be made if the improvement of the objective function value is more than 0.10 percent of the best objective function value prior to the last pattern move. The increment made to each parameter in a pattern move is based on the information gained from the local excursions such as the number of previous successful local excursions in the positive and the negative directions. The pattern move increment applied to each parameter during a pattern move is given by:

$$PINC = N * DELTA \tag{34}$$

where

$$N = n_1 - n_2 \tag{35}$$

and n_1 and n_2 are the number of previous successful positive and negative local excursions for a parameter. The purpose of this pattern move increment scheme is to allow for applying large increment to a parameter when the local excursions have shown a persistence of direction.

2. If the improvement of the objective function value is less than 0.10 percent of the best objective function value prior to the last pattern move, the DELTA values are halved. This step is called a resolution maneuver. The next local excursion maneuver is made with the reduced DELTA's.

3. If the results of the local excursion maneuver do not show an improvement, the pattern is destroyed and a new pattern move is started. A local excursion maneuver about the last accepted base point is initiated.

4. If the local excursion maneuver shows an improvement, a pattern move is made as discussed in item (1) above. If this pattern move fails to improve the objective function, a local excursion maneuver is made about this base point. If there is no improvement, the pattern is destroyed and a local excursion maneuver about the point prior to the last pattern move is started.

Objective Function

Three objective functions are provided to the user as criteria for goodness of fit.

1. Sum of the squares of the errors
2. Sum of the absolute value of the errors
3. Sum of the squared errors of the logarithms of the flows.

The above statistics are based on daily flows. The general form of the objective function as coded in the program is as follows:

$$\mathrm{OBFN} = \Sigma \, \frac{\mathrm{Abs}\ (\mathrm{Obs} - \mathrm{Sim})^{\mathrm{EXPA}}}{(\mathrm{Obs} + 0.00001)^{\mathrm{EXPB}}} \tag{36}$$

where

OBFN = objective function

Abs = absolute value

Obs = observed daily streamflow, mm

Sim = simulated daily streamflow, mm

EXPA and EXPB = read-in indicators to select an objective function

The user selects the value of EXPA and EXPB and accordingly determines which criterion of the above is to be selected. The value of EXPB was selected to be zero in all cases.

When EXPA = 1.0 the objective function selected is the sum of the absolute value of the errors.

$$OBFN = \Sigma \text{ Abs } (Obs - Sim) \quad (37)$$

When EXPA = 2.0, the objective function selected is the sum of the squares of errors.

$$OBFN = \Sigma (Obs - Sim)^2 \quad (38)$$

Finally, when EXPA = 0.0, the program artifically selects the log objective function as a criterion.

$$OBFN = \Sigma (\log (Obs) - \log (Sim))^{2.0} \quad (39)$$

or

$$OBFN = \Sigma (\log (Obs/Sim))^{2.0} \quad (40)$$

The user can terminate the pattern search routine by either specifying the maximum number of iteration or the maximum number of resolutions. The initial parameter values and their upper and lower limits and increments, DELTA's, are provided by the user.

The model is designed to encompass simulation and optimization. It performs simulation by reading the value of paramaters and constants and other required input data as described in the user's manual in Appendix I. On the other hand, the program is capable of performing parameter optimization by calling the subroutine PAROPT. The pattern search routine was modified to allow making a final simulation run after the optimization run is completed. Each time the optimization routine is called, the set of parameter values which corresponds to the minimum objective function value is saved in the computer memory. After the optimization routine is terminated, utilizing either criterion mentioned above, the final value of the optimized parameters which corresponds to the best value of the objective function and the other read-in constants are utilized to perform the final simulation run with a complete moisture accounting output. Description of computer output is shown in Appendix II.

CHAPTER IV

SIMULATION RESULTS AND DISCUSSION

The model was tested and applied to simulate streamflow of Zerqa River and one of its tributaries, Seil Zerqa. The first stage of the analysis was to run the model using the optimization option. One year of data was used to optimize the model parameters for two watersheds using the different objective functions. The second stage was to accept the optimized parameters to be the true ones and run the model using the simulation option in the program. Four years of Zerqa River streamflow and one year of Seil Zerqa streamflow were simulated.

Zerqa River Basin

General Physiography

The Zerqa River is the second principal tributary of the Jordan River in the reach between Lake Taberias and the Dead Sea. The watershed lies almost entirely within the Kingdom of Jordan to the north and east of Amman. The River drains an area of 3116 square kilometers at the gage site near New Jerash Road. The average slope of the river bed is about ten meters per kilometer. The watershed lies within the North-Eastern Highlands region and the Eastern Plateau region. The physiographical characteristics of the watershed are those of of these regions. The watershed headwaters elevation is about 1400 meters near Salkhad. The altitudes range from 600 to 800 meters in the Eastern Plateau and gradually descend to 100 meters below sea level near the gage site.

The watershed consists of about 40 tributaries longer than three kilometers. It is characterized by water regimes which are influenced by climatic conditions, topographic and geologic structure of the terrain, and by the state of the vegetal cover.

The Zerqa River System

The main tributaries of the Zerqa River are Wadi Dhuleil and Seil Zerqa (see Figure 14). Wadi Dhuleil drains an area of about 900 square kilometers at the Amman - Mafraq Highway. The southern slopes of Jebel (mountain) Druze located in southern Syria is drained by two principal tributaries, Wadi Ajib and Wadi Zaatari. Wadi Dhuleil eventually joins the Zerqa River at a point just north of the town of Sukhna. The wadi, including the previously mentioned tributaries, are dry except during periods of heavy rainfall, which generally occur about three to five times each winter. The runoff usually lasts from one to four days due to the lack of vegetation to hold the water back and let it be absorbed in the watershed basin.

Seil Zerqa, the second principal tributary, is a perennial wadi. It drains an area of about 652 square kilometers. The flow is continuous and is characterized by flood

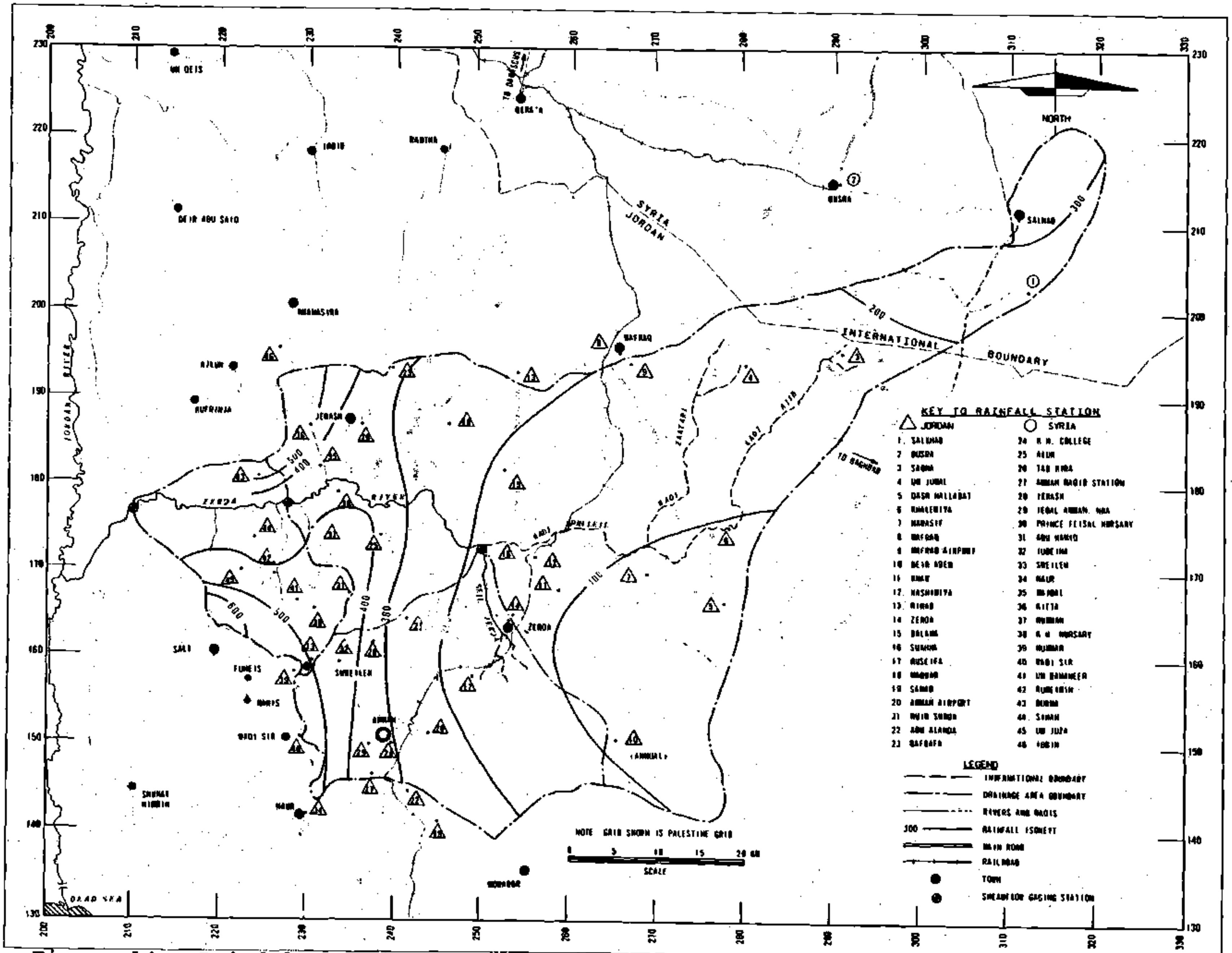


Figure 14. Rainfall Stations Network in the Zerqa River Watershed and Average Annual Rainfall.

flows during the winter and low flows during the dry summer. The Seil joins the river at a point near Sukhna after which the river flows all year around.

<u>Geohydrology of Zerqa River Watershed</u>

The principal source of water supply in this area is the alluvial sand and gravel of the valley fill of Wadi Zerqa. The mountains enclosing or adjacent to the wadi basin are usually the only areas that receive sufficient precipitation to produce direct recharge to the groundwater storage. In order to understand the geohydrology of Zerqa River watershed, a brief description of the developed groundwater field in the area, as discussed by Mudallal[13], is given below.

There are two important developed groundwater fields located in the Zerqa River watershed.

1. Amman-Zerqa Groundwater field

This field covers the area which extends from Amman, northward to Sukhna area, along Seil Zerqa, where Wadi Dhuleil joins Zerqa River about 30 kilometers north east of Amman.

The main aquifers in the area are:

a. The gravel deposits
b. Amman Formation, B-2
c. Wadi Sir Formation, A-7
d. Hummer Formation, A-4

Water depth in the gravel aquifer is shallow, while the water depth in the A-4 aquifer is much deeper. The depth of wells ranges between ten meters in the gravel aquifer to

350 meters in the A-4 aquifer. The relative shallow depth of groundwater in the top aquifer in this area causes groundwater to contribute base flow to the Zerqa River during the winter and the summer seasons.

2. Dhuleil Groundwater field

The main aquifer in the area is the Basalt rocks. The underlying formations of Wadi Sir, A-7, and Amman Formation, B-2, were found to be poor aquifers. However, formations which constitute the aquifers to the south of the basaltic aquifer are considered to be good aquifers.

The depth to groundwater level in the area varies between 58 to 84 meters. This depth is much greater than in the gravel deposit aquifers of the Amman-Zerqa groundwater field. Due to the deep water level and to the relatively flat topography of Wadi Dhuleil, there is no base flow contributed by the groundwater. The wadi is called a dry wadi or non-perennial wadi.

The high rainfall (averaging above 600 mm annually in the Ajlun area) permits good groundwater replenishment, and the lower outcrops yield abundant springs. In Wadi Zerqa there are high-level springs from the Cenomanian limestone around Ajlun and Jerash. The main springs (Sukhna, Temera, and Tufuriah) however, are located at lower elevations in the Cenomanian limestone. Further up in Wadi Zerqa, the springs at the towns of Zerqa and Ruseifa come from chert beds of the upper Senonian.

Rainfall

The rainfall-measuring network on the Zerqa River basin consists of 46 stations as shown in Figure 14. The selected period of analysis is five years, beginning with the 1969 water year. Figure 14 also illustrates the average annual rainfall in mm for the 30 years from 1931 to 1960 as prepared by the Natural Resources Authority. Five isohyetal maps were prepared for the period of analysis as shown in Figure 15 through Figure 19. Stations with continuous records throughout the year were utilized in producing the isohyetal maps. The variability of rainfall from year to year makes it necessary to establish an isohyetal map for each individual year.

The average rainfall over the basins were computed utilizing Program WTRAIN. Table 7 and Table 8 lists, for each year, the selected rainfall stations and their corresponding weight for the Zerqa River basin and Seil Zerqa basin, respectively.

Streamflow

The streamflow data used for fitting the model to the Zerqa River and the Seil Zerqa basins were those recorded at the N.R.A. stream gaging stations near New Jerash Road and near the village of Sukhna. Five years of records, beginning with the water year 1969, were obtained from the N.R.A. for the Zerqa River. The mean annual discharge for this period was 14.57 mm over the basin. The maximum flow of 107.00 cubic feet per second occurred April 13, 1971. The annual

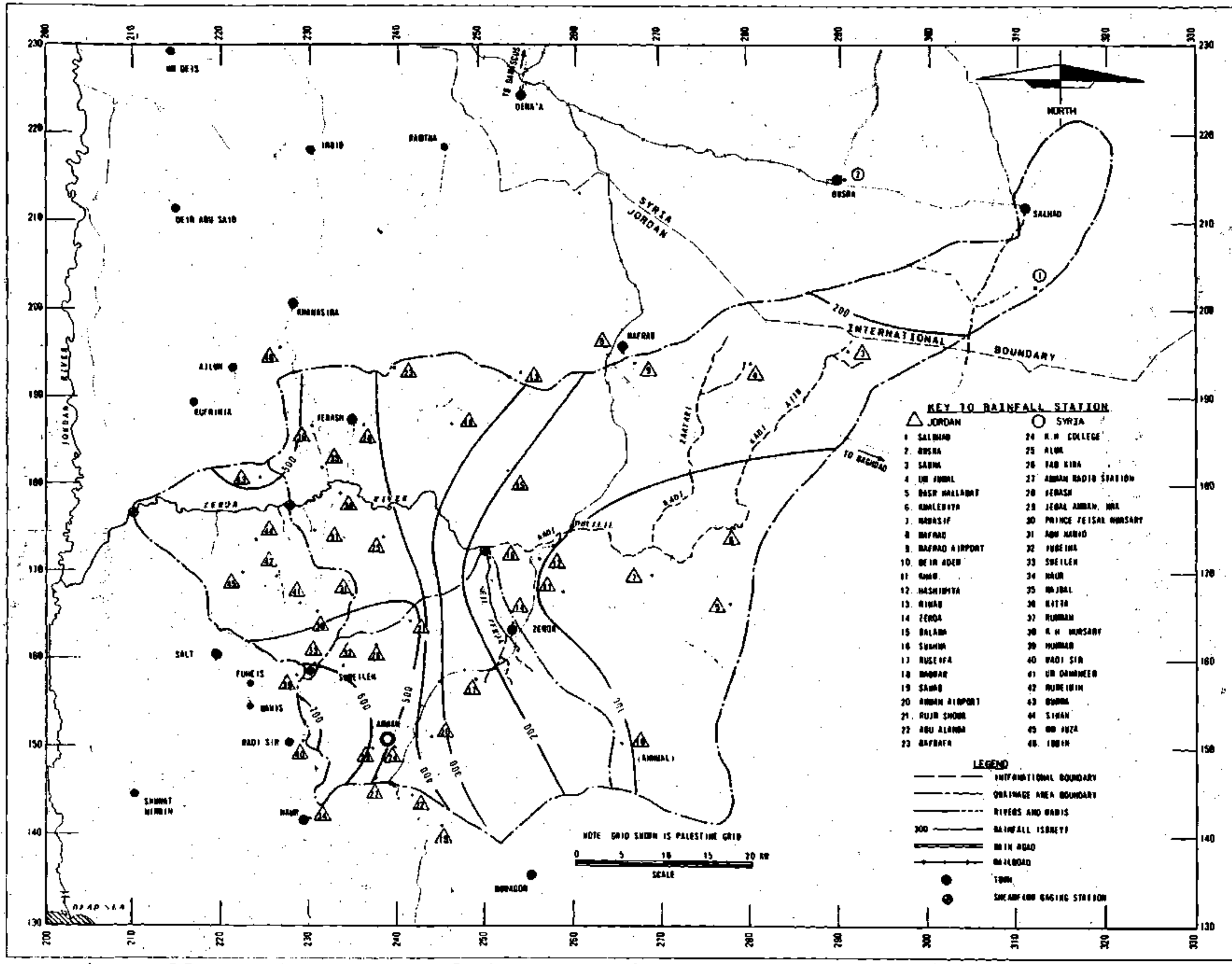


Figure 15. Isohyetal Map of the Zerqa River Watershed for the 1969 Water Year.

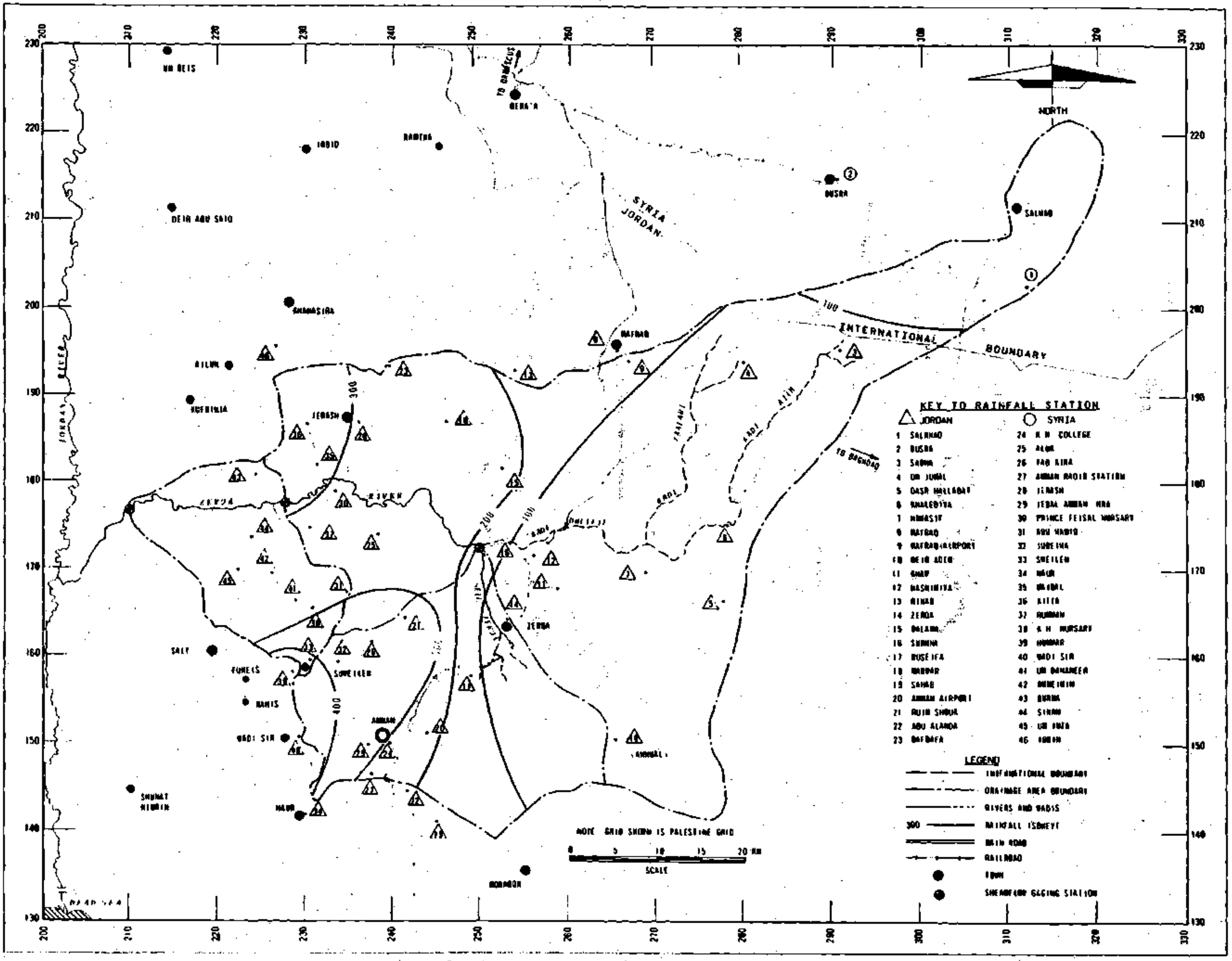


Figure 16. Isohyetal Map of the Zerqa River Watershed for the 1970 Water Year.

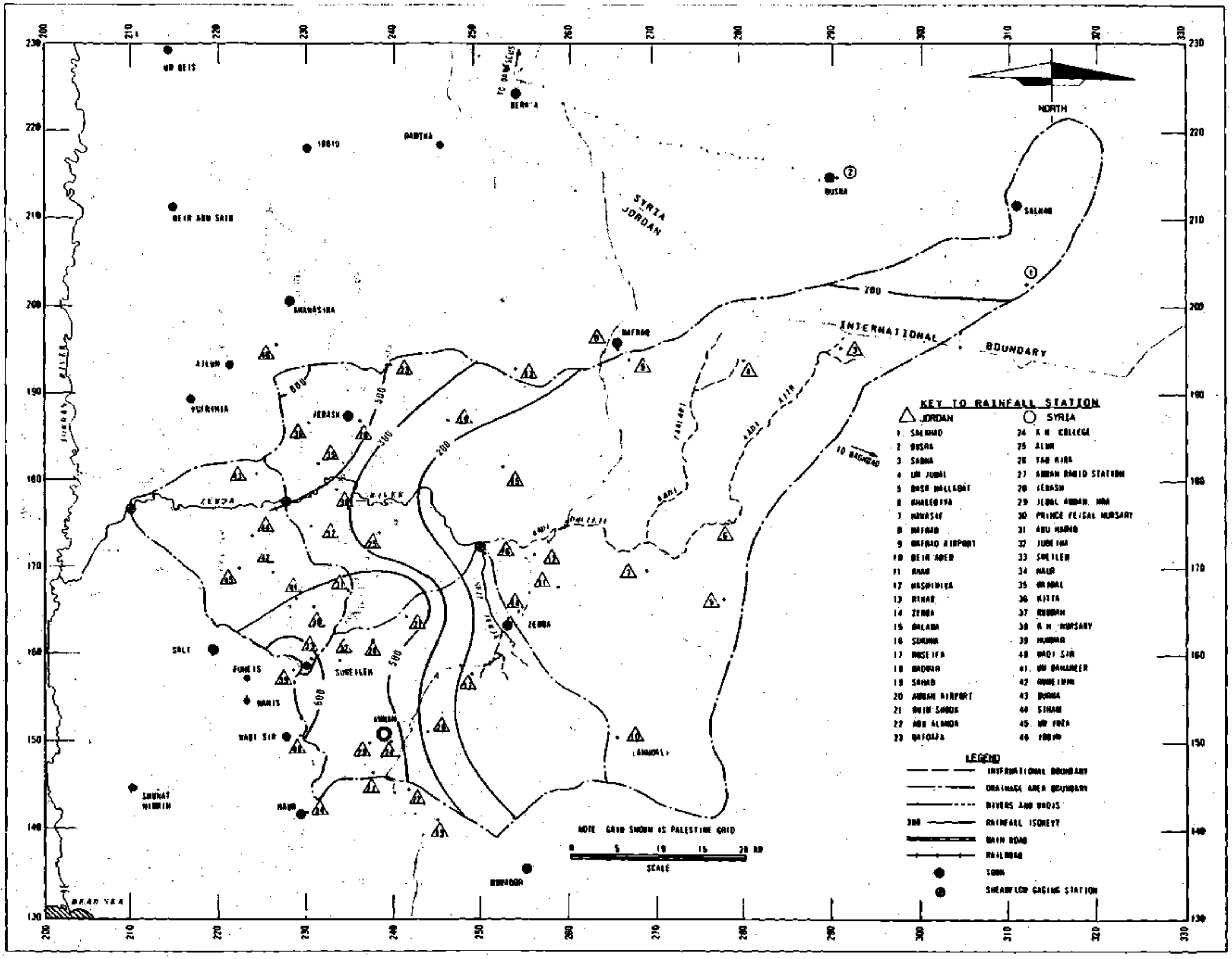


Figure 17. Isohyetal Map of the Zerqa River Watershed for the 1971 Water Year.

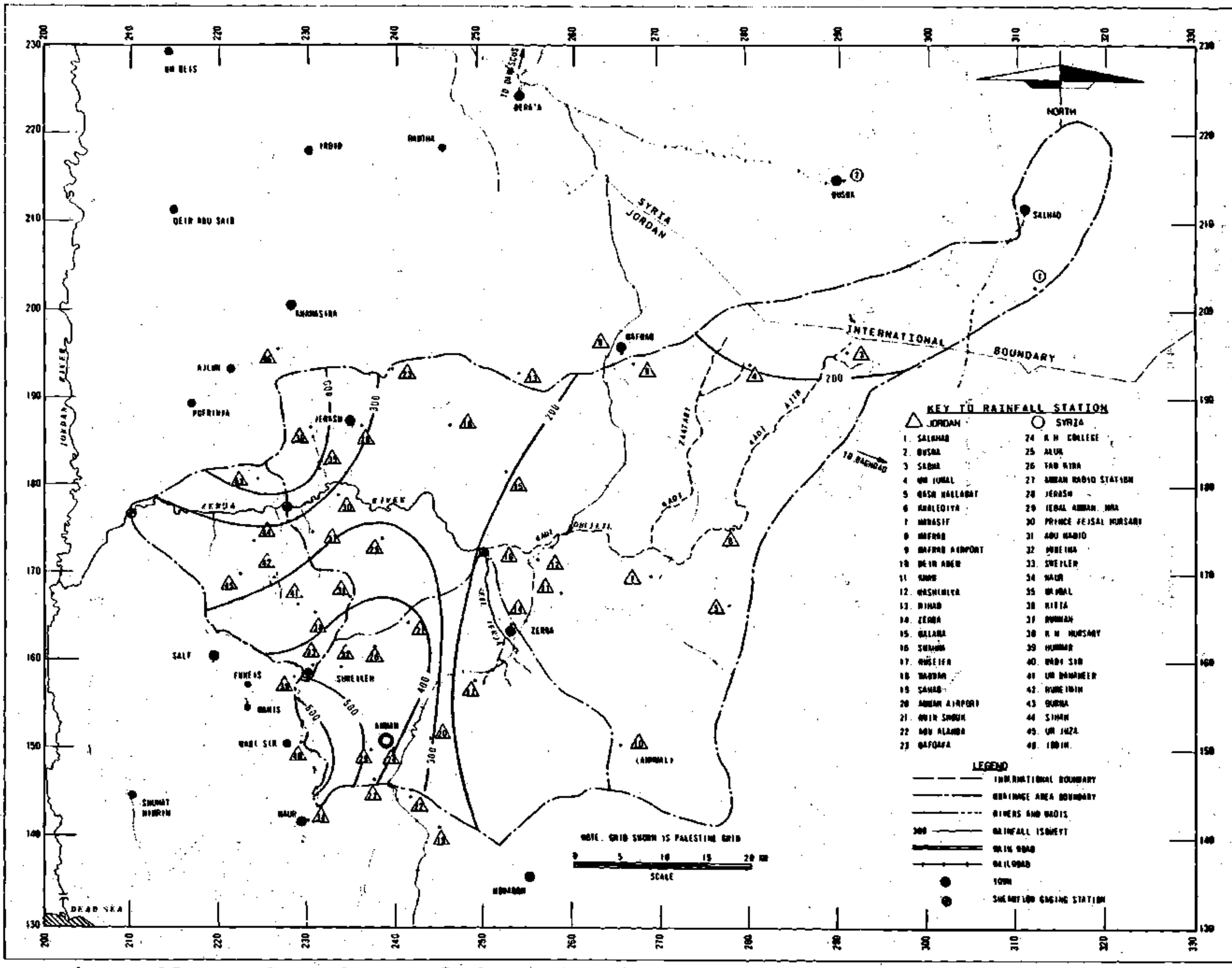


Figure 18. Isohyetal Map of the Zerqa River Watershed for the 1972 Water Year.

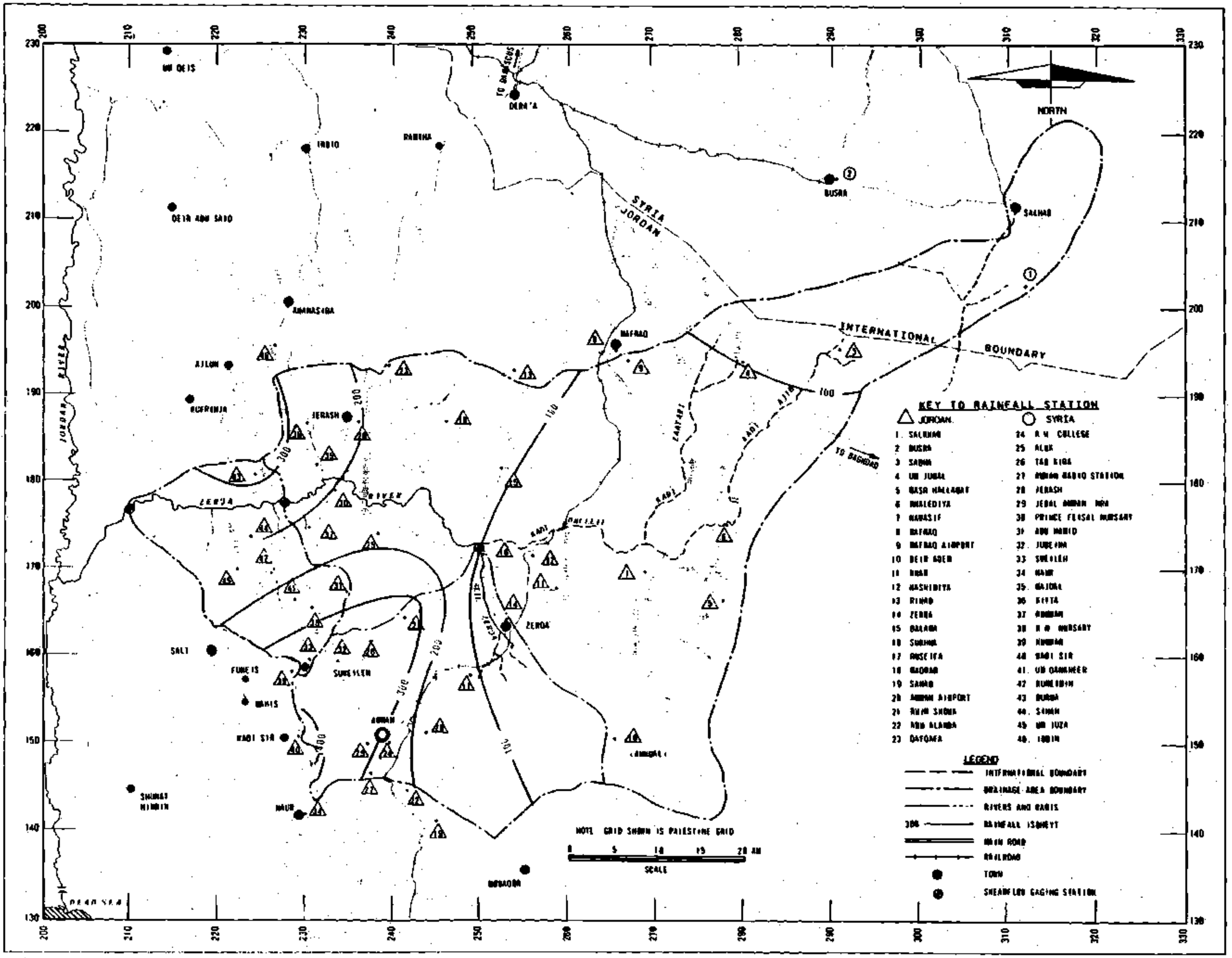


Figure 19. Isohyetal Map of the Zerqa River Watershed for the 1973 Water Year.

Table 7. Rainfall Station Weight for the Zerqa River Basin

Water Year	Sta. Number	2	5	9	15	20	24	25	39
1968/1969	Sta. Weight	.093	.205	.315	.133	.100	.032	.100	.022
Water Year	Sta. Number	2	4	19	25	29	36	40	
1969/1970	Sta. Weight	.077	.516	.113	.196	.056	.032	.010	
Water Year	Sta. Number	2	16	25	29	30	35		
1970/1971	Sta. Weight	.061	.660	.095	.067	.077	.040		
Water Year	Sta. Number	2	17	19	24	25	28	35	39
1971/1972	Sta. Weight	.144	.542	.158	.046	.046	.021	.021	.022
Water Year	Sta. Number	2	14	15	29	35	41		
1972/1973	Sta. Weight	.156	.477	.235	.057	.044	.031		

Table 8. Rainfall Station Weight for Seil Zerqa Basin

Water Year	Sta. Number	17	19	24	25	39
1971/1972	Sta. Weight	.511	.117	.172	.094	.106
Water Year	Sta. Number	14	15	29	41	
1972/1973	Sta. Weight	.304	.351	.236	.109	

peak during the period of study varied from 10.40 to 107.00 cubic meters per second. The Zerqa River flood Flow is characterized by a sharp rise of the flood hydrograph and a quick recession. Low flows are characteristic of the streamflow during the rainless days. Low flow during the period varied from 0.160 to 0.670 cubic meters per second.

The streamflow station on Seil Zerqa was established in 1971. Two years of records, beginning with the water year 1972, were obtained. Although the information from two years of streamflow records is not sufficient to make an assessment of streamflow characteristics, the following information is given. The mean annual discharge for the two years was 23.78 mm over the basin. The maximum flow of 28.30 cubic meters per second occurred December 7, 1972. The annual peak during the period varied from 8.92 to 28.30 cubic meters per second. Flow characteristics are similar to those of Zerqa River. Low flows dominated the streamflow record and reached to a minimum value of 0.02 cubic meters per second.

Evaporation

Daily values of pan evaporation, obtained from the N.R.A., were recorded at King Hussein Evaporation station near Amman. No record is available for the water year 1971 at this station. Daily values of pan evaporation used for this year were recorded at Ras Munif Evaporation station near Ibbin. The average annual pan evaporation measurement during the period 1969-1973 was 2587 mm.

Man-Made Activities in the Watershed

In some areas, the discharge of springs may represent a moderate to large proportion of the total natural discharge of groundwater. The discharge may be localized in well-defined channels and thus be susceptible to accurate measurement. In other places, however, only a small fraction of the spring discharge is channelized with the remainder issuing as seeps over an extensive area. In the later case the channel flow is a poor indicator of total discharge. Springs in the Zerqa River watershed are fully utilized for water supply and irrigation usage. In addition, diversion of portions of channel flow is commonly practiced in the area, especially in the period after flooding events and during the summer droughts. This practice can be detected from streamflow measurements.

In areas of groundwater development, withdrawal from wells is commonly a significant part of the total groundwater discharge. Infiltration from deep aquifers is probably the major source of underground water. Groundwater recharge occurs where formations outcrop at higher elevations where higher rainfall occurs. The groundwater then descends into the valley confined above and below by impermeable formations. Strong flows along the fault zones are to be expected.[14] In areas where the top formations have been removed, numerous springs flow from the lower formations.

In the light of the above information and from the streamflow data inspection, streamflow measurements fail, in some instances, to represent the natural response of the watershed.

Analysis of Results

The procedure of analysis adopted, for each watershed, was to run the optimization routine for one water year. The final parameter values were used to run the simulation model. Appendix II contains the computer output of the optimization and simulation runs for the Zerqa River and Seil Zerqa watersheds. It is advisable to refer to this Appendix in order to be familiar with the output description.

Zerqa River Streamflow Simulation

The 1969 water year was selected for the optimization run. The fixed parameter values and the initial values of the optimized parameters were estimated. Two runs were made. The objective function of the first run was the sum of absolute value of the errors (EXPA = 1.00). The second optimization run utilized the sum of the squared errors of the logarithms of the flows as the objective function. The sum of the squares of the errors objective function was not used because of the domination of low flows in the streamflow record. The final values of the optimized parameters using the two objective functions are listed in Table 9 and Table 10. It can be seen that the optimum parameter values are reasonable, stable, and within the lower and the upper limits. The values of the maximum infiltration rate, FMAX, are similar

Table 9. List of the Fixed Parameter Values and the Initial and Final Values of the Optimized Parameters for the Zerga River Watershed Utilizing the Sum of the Absolute Value of the Flow Errors Objective Function.

THE FOLLOWING IS THE FIXED AND INITIAL PARAMETER VALUES

PARAMETER	BSMI	BGWR	WCEPT	SQKM	FRCK	SGWK	PGWK	SROK	PIMP	TRLOS
FIXED VALUE	20.000	33.000	4.000	3116.000	.300	.990	.999	.250	0.000	0.000

PARAMETER	FMAX	FMIN	ALFN	AHORD	BHORP	FSRO	REXP	BHORD	EPAR	DLOSS
INITIAL VALUE	420.000	30.000	.100	50.000	10.000	.100	1.000	90.000	.500	0.000
UPPER LIMIT	600.000	60.000	.400	100.000	50.000	.150	4.000	200.000	1.000	.800
LOWER LIMIT	300.000	10.000	.050	20.000	5.000	.100	1.000	60.000	.500	0.000
INCREMENT	5.000	1.000	.005	1.000	1.000	.005	.050	1.000	.025	.025

THE FOLLOWING IS THE FINAL OPTIMIZATION RESULTS

PARAMETER	FMAX	FMIN	ALFN	AHORD	BHORP	FSRO	REXP	BHORD	EPAR	DLOSS
BEST VALUE	595.000	33.000	.060	60.000	10.000	.145	2.000	105.000	.725	.450

STATISTICS	EXPA	EXPB	ERROR	SSERR	SSLOG	ABSV	OBFN	CCOF	SLOPE	YINT
	1.0000	0.0000	2.0576	2.1481	6.3310	6.5637	6.5637	.9144	1.0766	-.0045

Table 10. List of the Fixed Parameter Values and the Initial and Final Values of the Optimized Parameters for the Zerga River Watershed Utilizing the Sum of the Squared Errors of the Flow Logarithms Objective Function.

THE FOLLOWING IS THE FIXED AND INITIAL PARAMETER VALUES

PARAMETER	BSMI	BGWR	WCEPT	SQKM	FRCK	SGWK	PGWK	SROK	PIMP	TRLOS
FIXED VALUE	20.000	33.000	4.000	3116.000	.300	.990	.999	.250	0.000	0.000

PARAMETER	FMAX	FMIN	ALFN	AHORD	BHORP	FSRO	REXP	BHORD	EPAR	OLOSS
INITIAL VALUE	420.000	30.000	.100	50.000	10.000	.100	1.000	90.000	.500	0.000
UPPER LIMIT	600.000	60.000	.400	100.000	50.000	.150	4.000	200.000	1.000	.800
LOWER LIMIT	300.000	10.000	.050	20.000	5.000	.100	1.000	60.000	.500	0.000
INCREMENT	5.000	1.000	.005	1.000	1.000	.005	.050	1.000	.025	.025

THE FOLLOWING IS THE FINAL OPTIMIZATION RESULTS

PARAMETER	FMAX	FMIN	ALFN	AHORD	BHORP	FSRO	REXP	BHORD	EPAR	OLOSS
BEST VALUE	450.000	55.000	.070	70.000	6.000	.140	1.200	134.000	.800	.250

STATISTICS	EXPA	EXPB	ERROR	SSERR	SSLOG	ABSV	OBFN	CCOF	SLOPE	YINT
	0.0000	0.0000	.5100	2.5335	5.7517	7.2112	5.7517	.8952	1.0050	-.0003

to those used in the Harza-Baker Report.[6] The soil moisture capacity, the sum of AHORD and BHORD, has values which are in close agreement to the limited soil information concluded by Sir MacDonald, the British consultant.

The value of the optimized parameter BHORP (maximum permeability rate in B Horizon) indicates slow water movement from A Horizon to B Horizon due to compact and rocky soils at shallow depths. This slow movement allows a large portion of the incoming moisture to stay in A Horizon storage and evaporate. This is consistant with the high rate of evaporation from the top soil.

The initial value of the deep losses parameter, DLOSS, was set to zero. The upper limit was set to 0.800. The final value after optimization, using the absolute value objective function, was 0.450. The model indicates that 45 percent of the moisture which percolates from the B Horizon moisture storage appears in the form of springs or seeps or percolates to deep aquifers in the area.

Statistical analyses were performed on the simulated daily flows in each iteration during the optimization run. Each time the correlation coefficient, the slope and the intercept of the regression line, the sum of the absolute value of the errors, the sum of the squared errors logarithms and the sum of the squared errors are computed and listed. The purpose of these statistics is to provide a measure of simulation improvement from iteration to iteration during the optimization run. The sum of the absolute value of the errors and the sum of the squared errors are used to compute the average absolute value of prediction error, expressed in a percentage, and the standard error of prediction, respectively. The statistical values listed in Table 11 are the final values resulting from use of the two objective functions in the optimization runs for the 1969 water year. A perfect fit would result in a correlation coefficient equal to 1.0, a regression line slope of 1.0, an intercept of 0.0, an average absolute value of prediction error and a standard error of prediction of 0.0 percent.

It can be concluded after examining Table 9 and Table 10 that the differences resulting from using the sum of the absolute value of the errors rather than the sum of the squared errors of the logarithms of flows is not substantial. This can be further illustrated by the daily hydrograph plots as shown in Figure 20 and Figure 21 and by the small differences between the statistical values for each optimization criterion as can be seen in Table 11. Therefore, the selection of a criterion of the goodness of fit is not crucial as long as it is one of these two functions. However, it should be emphasized that the sum of the absolute value of the errors criterion tends to better match the peaks while the sum of the squared errors of the logarithms of the flows criterion tends to equalize the percentage error of the high and low flows.

Table 11. Comparison of Computed Statistics of Daily Flows of the Zerqa River for the 1969 Water Year.

Computed Statistics	Optimization Criterion: Sum of the Absolute Value of Daily Errors	Optimization Criterion: Sum of the Squared Daily Error Logarithms
Correlation coefficient	0.9144	0.8952
Regression Line Slope	1.0706	1.0050
Regression Line Intercept	-0.0045	-0.0003
Abs. Value of Errors	6.56	7.21
Squared Errors Logarithms	6.33	5.75
Sum of Squared Errors	2.15	2.53

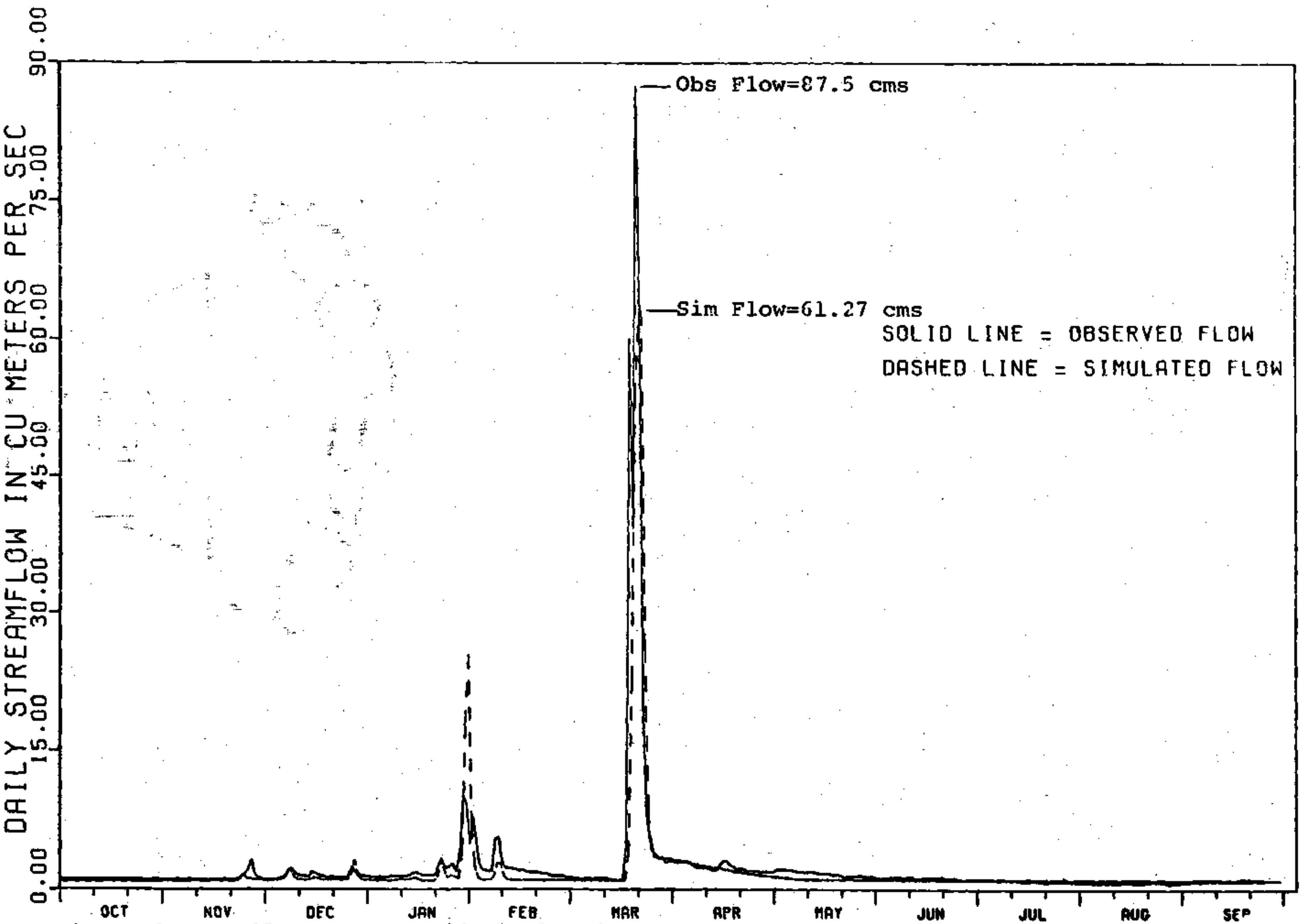


Figure 20. Daily Observed and Simulated Flows of the Zerqa River for the 1969 Water Year Utilizing the Sum of the Absolute Value of the Errors Objective Function.

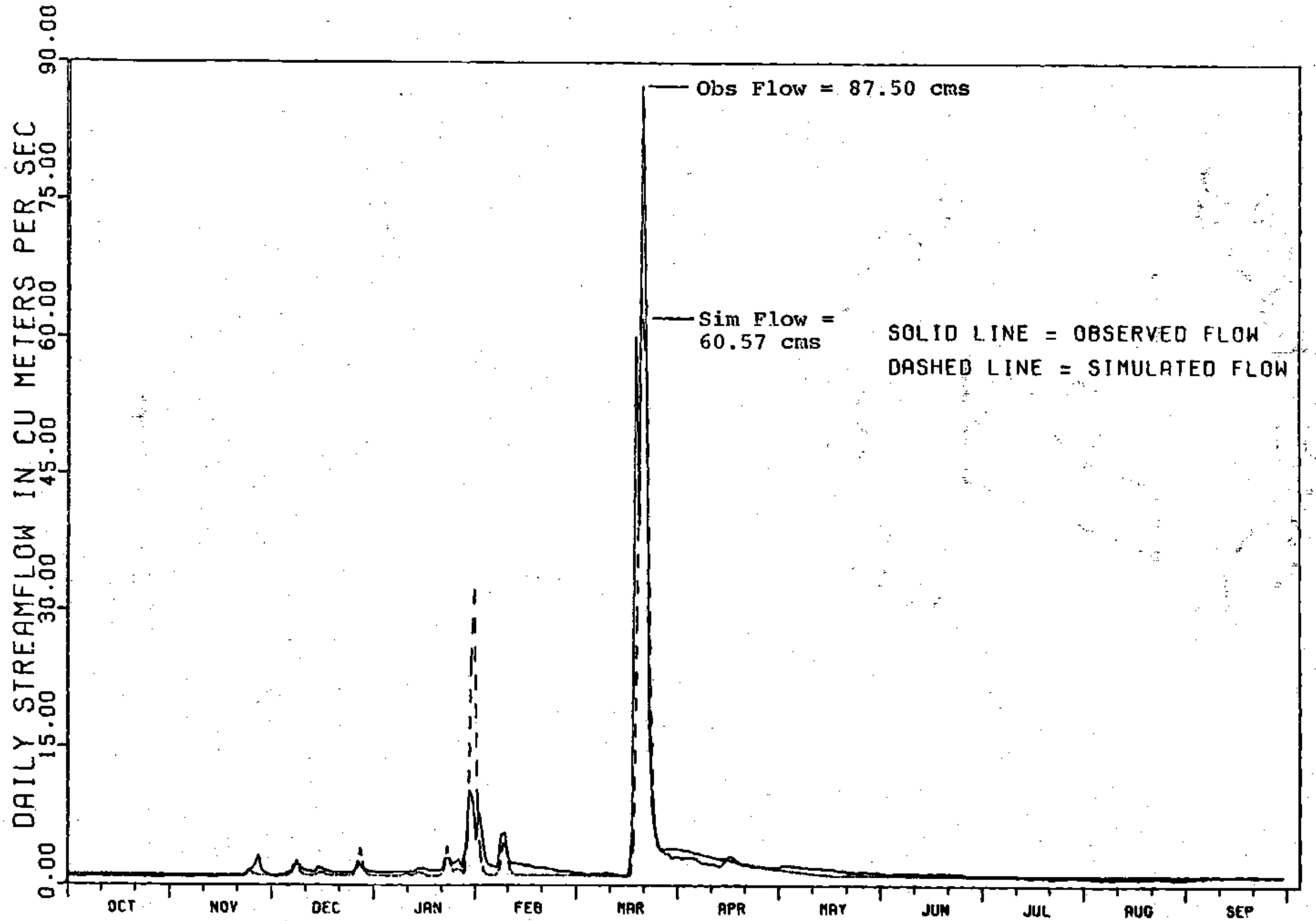


Figure 21. Daily Observed and Simulated Flows of the Zerqa River for the 1969 Water Year Utilizing the Sum of the Squared Errors of the Flow Logarithms Objective Function.

Comparison of the two objective functions was made using the monthly flows. Table 12 lists the observed and simulated monthly flows for the 1969 water year. Close agreement between the observed and the simulated flows can be concluded in both cases. The simulated monthly flows are plotted against the observed flows in each case. The equal value lines for these flows are plotted in Figure 22 and Figure 23.

The degree of the simulation accuracy can be measured by computing the percentage error of the predicted flows, namely, the standard error of prediction and the average absolute value of the simulation error. The standard error is computed as the square root of the mean of the sum of the squared errors divided by the mean of the observed streamflows. The effect of the flood flow errors on the standard error value is greatly magnified and the effect of the low flow errors is sharply reduced. The average absolute value of the error is computed by dividing the sum of the absolute value of the errors by the mean of the observed flows. The effect of the flood flow errors on the average absolute value of the error is less pronounced.

The statistical values in Table 11 were used to demonstrate the effect of flood flow errors on the standard error of prediction for the calibrated 1969 water year. Low flows and small flood flows were well simulated (refer to Figure 20). However, simulation of the large flood flows was not as accurate as low flows simulation. This is partly due to

Table 12. Monthly Observed and Simulated Flows of the Zerqa River for the 1969 Water Year.

Month	Observed Flow, mm	Simulated* Flow, mm	Simulated** Flow, mm
October	0.79	1.01	1.01
November	0.97	0.97	0.98
December	1.30	1.13	1.20
Janaury	2.11	2.50	3.02
February	2.03	1.04	1.18
March	9.07	7.81	8.03
April	2.07	1.98	2.44
May	1.52	1.06	1.17
June	1.04	0.95	0.96
July	0.85	0.96	0.96
August	0.67	0.93	0.93
September	0.87	0.87	0.88
Annual	23.29	21.21	22.76

*The sum of absolute value of errors.
**The sum of the squared of the error logarithms.

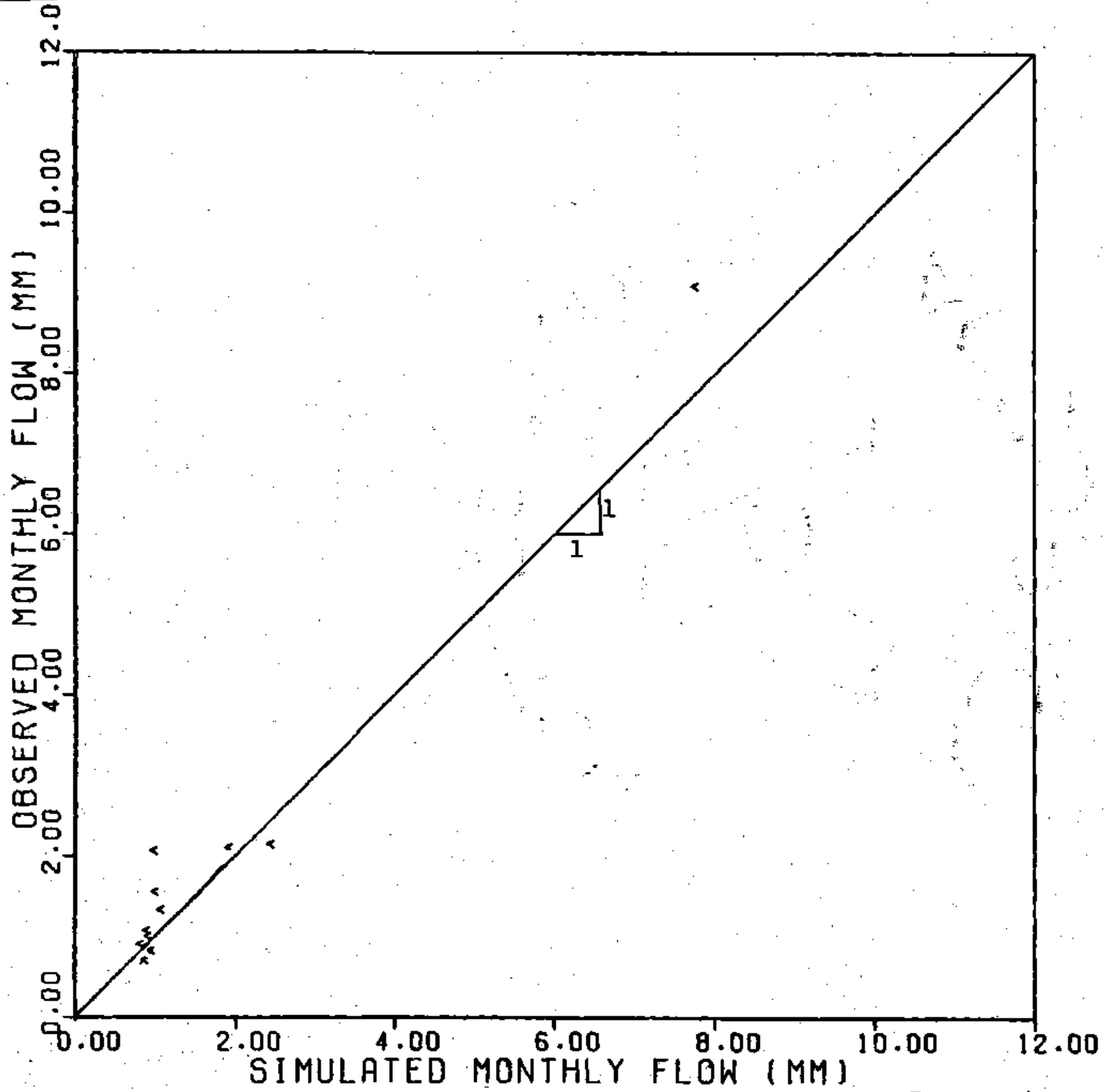


Figure 22. Scatter Diagram for the Simulation Results for the Zerqa River Monthly Streamflows of the 1969 Water Year Utilizing the Sum of the Absolute Value of the Errors Objective Function.

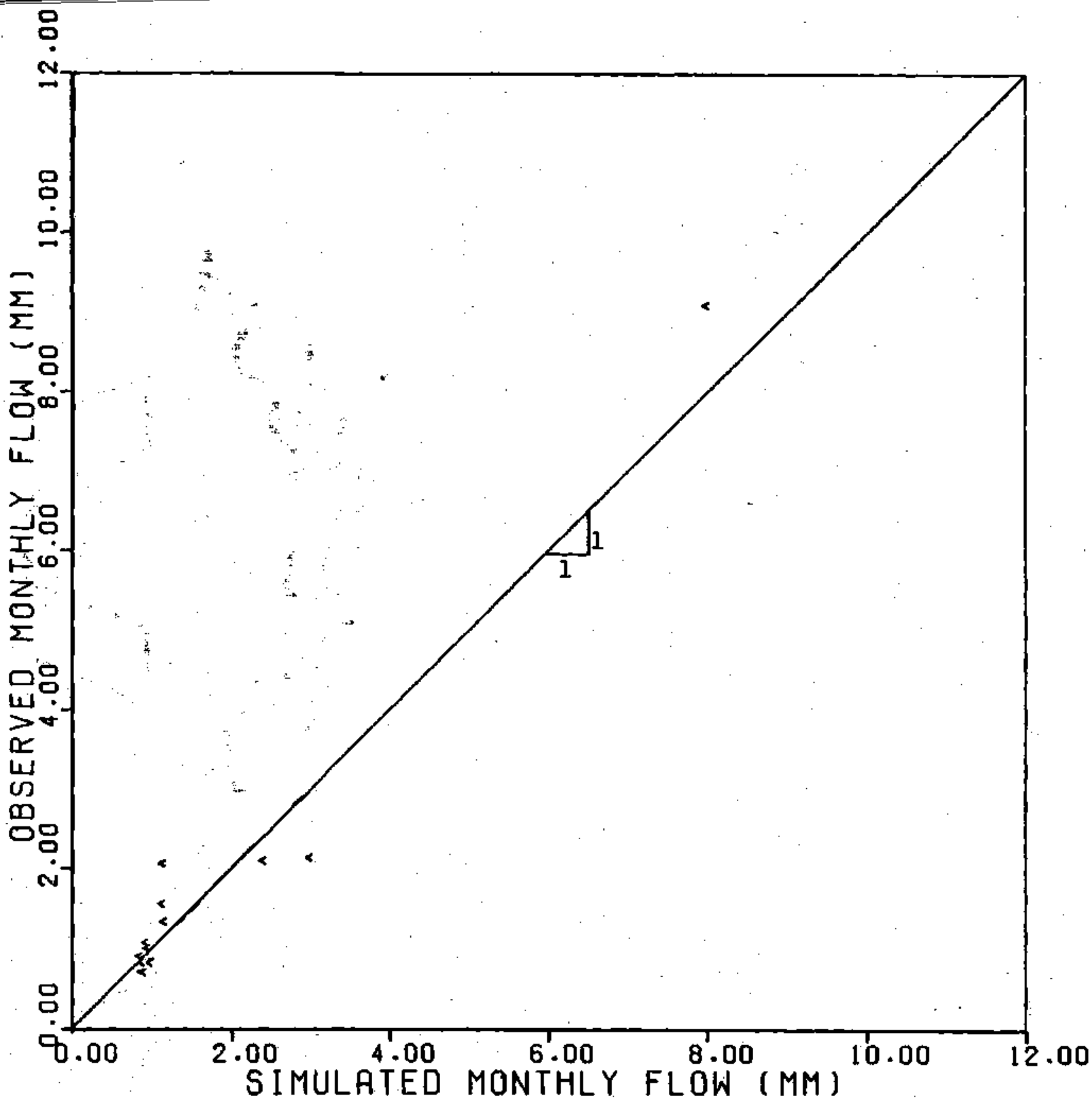


Figure 23. Scatter Diagram for the Simulation Results for the Zerqa River Monthly Streamflows of the 1969 Water Year Utilizing the Sum of the Squared Errors of the Flow Logarithms Objective Function.

errors in rainfall or streamflow records. Streamflow record shows a peak discharge of 7.95 cubic meters per second on February 1, 1969. No rainfall was recorded from January 30, 1969 to February 6, 1969. The sum of the squared errors of the simulated flows was 2.148 square millimeters which corresponds to a standard error of daily prediction of 120 percent. If the simulated flood flows during the periods from January 29, 1969 to February 2, 1969 and from March 19, 1969 to March 26, 1969 were excluded, the sum of the squared errors was 0.058 square millimeters which corresponds to a standard error of daily flows prediction of 32 percent. The sum of the squared error of the simulated peak on March 20, 1969 was about half of that for the simulated flows of the entire year. It can be concluded that if a close agreement between several simulated and observed flood flows cannot be reached, due to unsuccessful simulation or due to data errors at high peaks, a large standard error value results. The standard error of prediction of the monthly flows was computed and has a value of 26 percent. When the simulated monthly flows of January, February and March were excluded, a standard error of prediction of 18 percent was achieved. The average absolute value of the daily and monthly flows errors were computed utilizing all simulated flows of the 1969 water year. The average absolute value of the daily flows error was 28 percent and that of the monthly flows was 17 percent.

The final values of the optimized parameters resulting from the optimization run, utilizing the sum of the absolute value of the errors as a criterion of goodness of fit, were selected for the simulation run. Streamflow simulation was carried out for a period of four years beginning with the 1970 water year. Figure 24 through Figure 27 are the daily streamflow hydrographs for the entire period. Man-made activities such as flow diversion can be easily detected by examining the streamflow hydrographys. The period which begins on May of the 1972 water year (Figure 26) and ends on November of the following water year (Figure 27) is a prime example. It is apparent that diversion, probably for irrigation purposes, started on May, 1972, where a sharp drop between the simulated and the observed flow can be noted. The water from return irrigation started to contribute gradually to the streamflow. During this period, the observed flow was rising to catch up with the simulated flow on November, 1972. Excluding this phenomenon low flows can be considered well simulated throughout the four year period.

Flood flows simulation is not on the same level of accuracy as the low flows. It is not the intention to attribute lesser accuracy to the quality of data, but striking examples of such quality are given (refer to Figure 24). A peak discharge of 11.300 cubic meters per second was recorded on January 10, 1970. The only rainfall measurements recorded were 1.00 millimeter in Station No. 4 (Um Jumal) on January 9 and 0.50 millimeter in Station No. 29 (Jebel Amman, NRA)

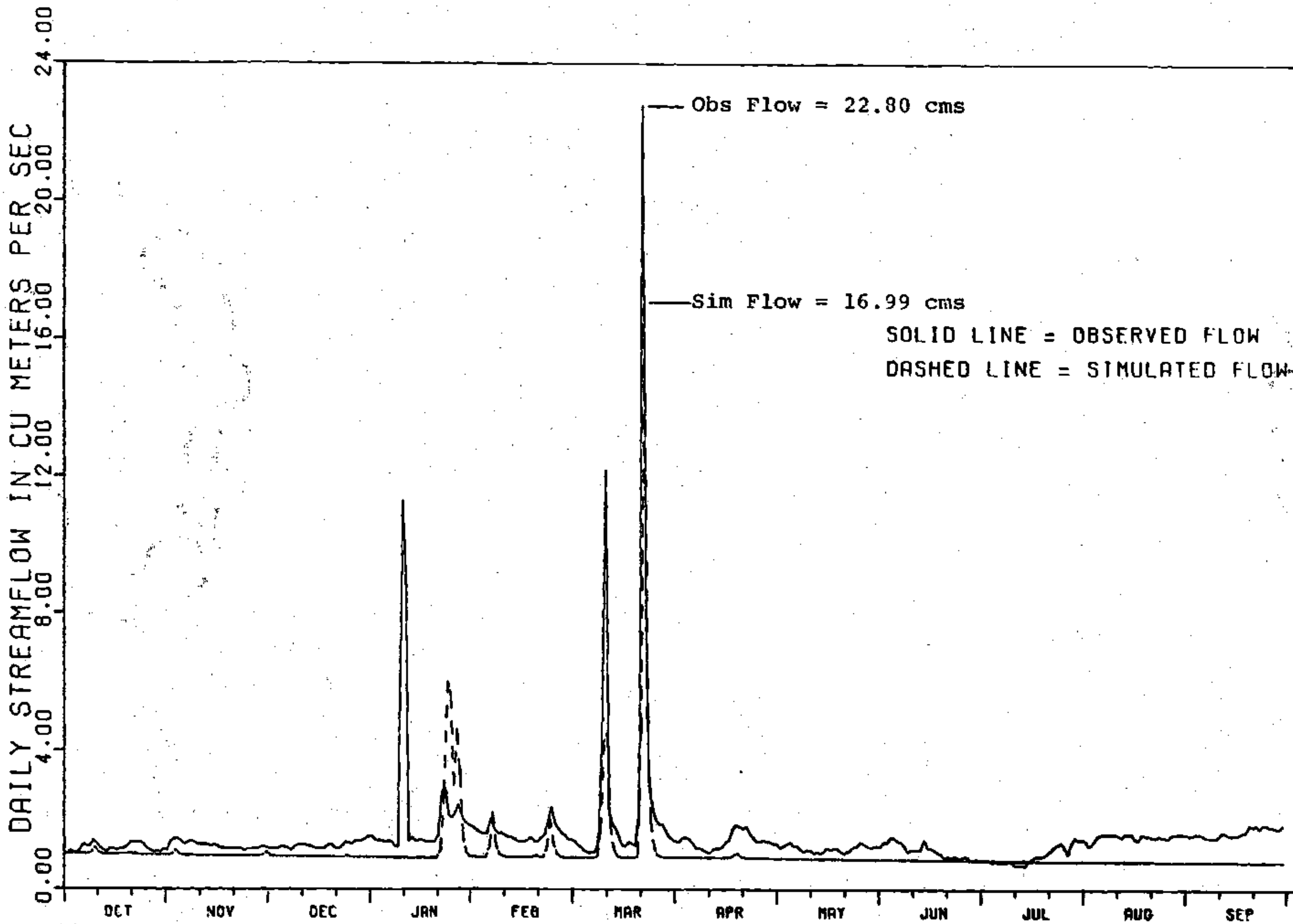


Figure 24. Daily Observed and Simulated Flows of the Zerqa River for the 1970 Water Year.

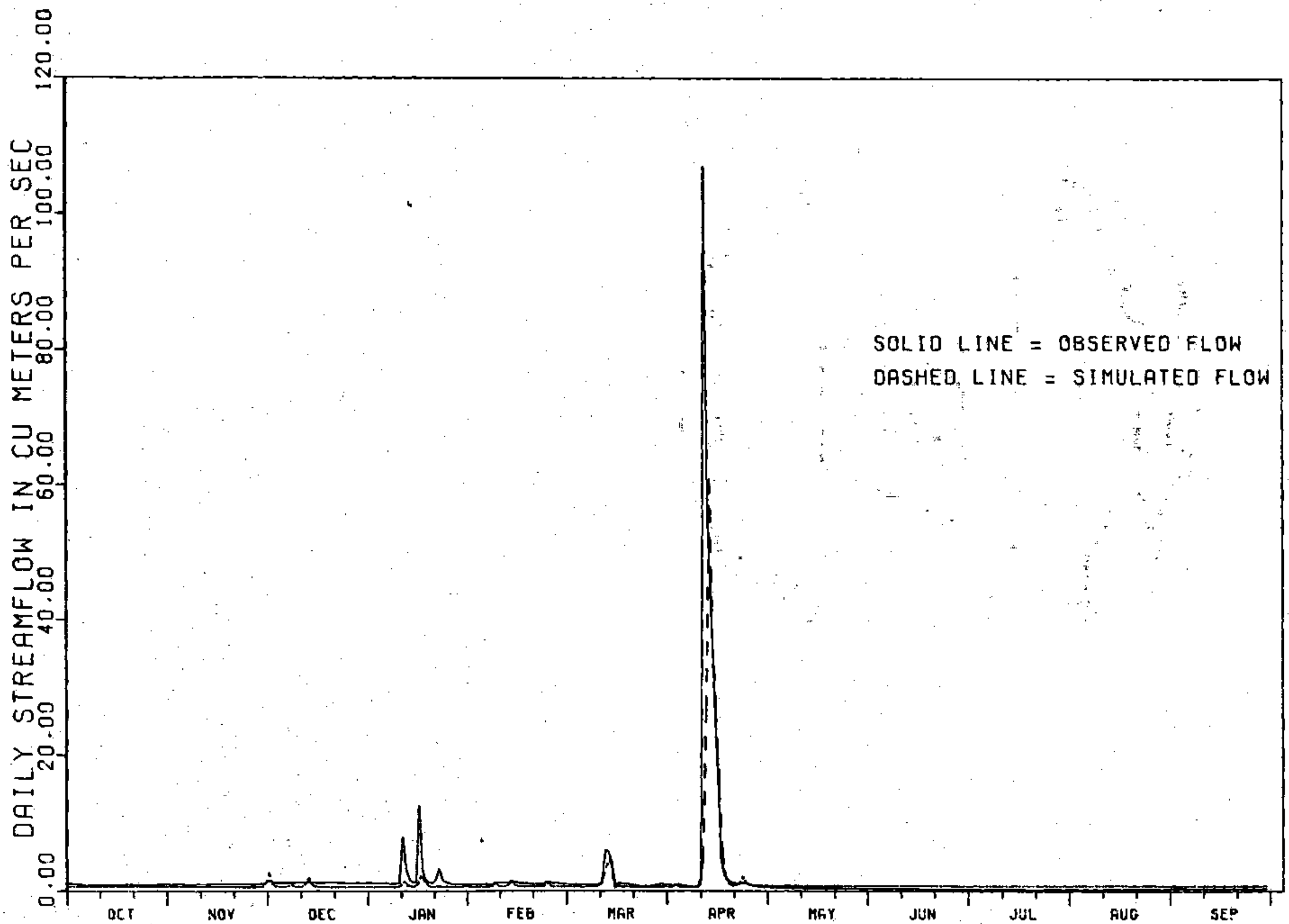


Figure 25. Daily Observed and Simulated Flows of the Zerqa River for the 1971 Water Year.

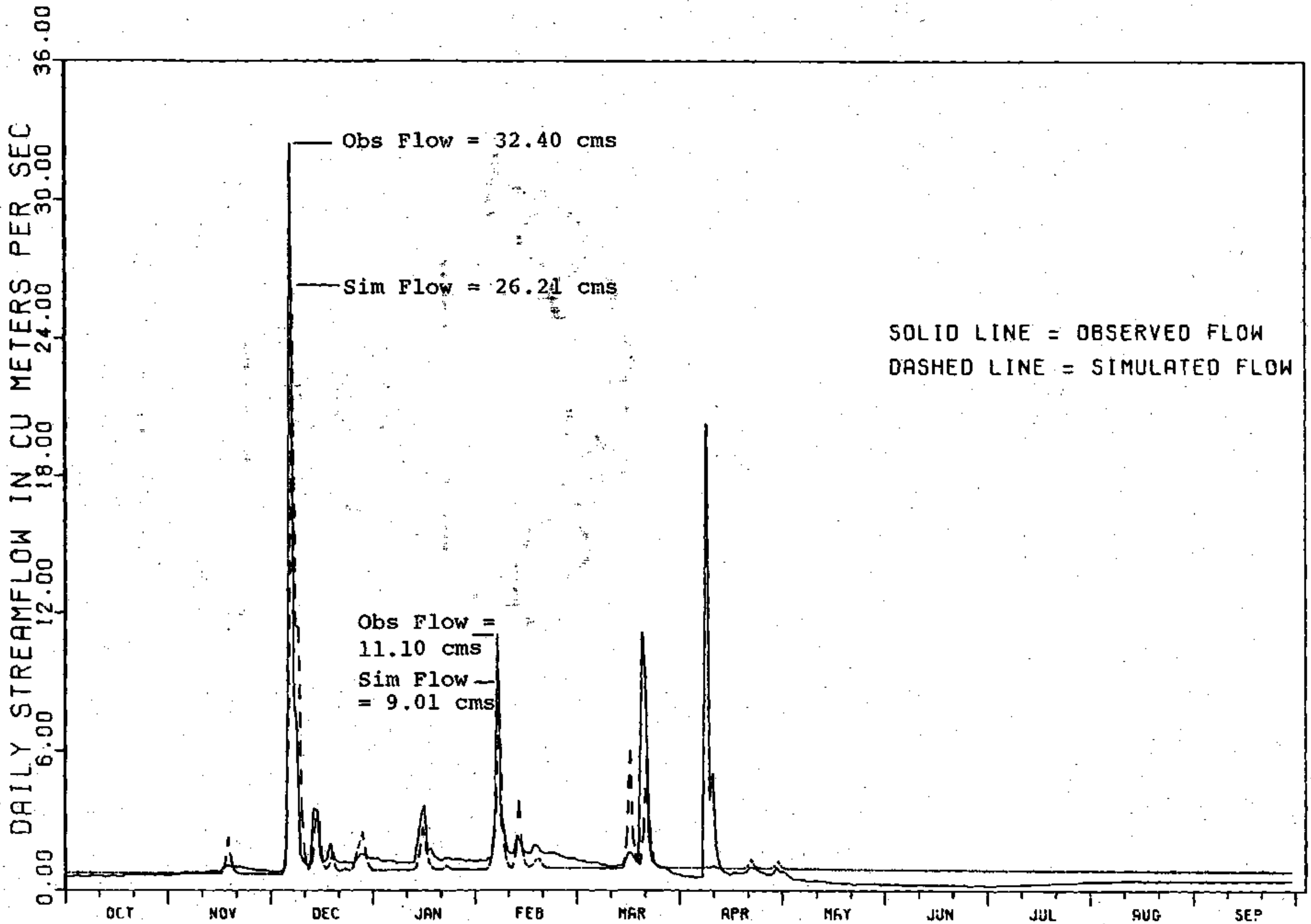


Figure 26. Daily Observed and Simulated Flows fo the Zerqa River for the 1972 Water Year.

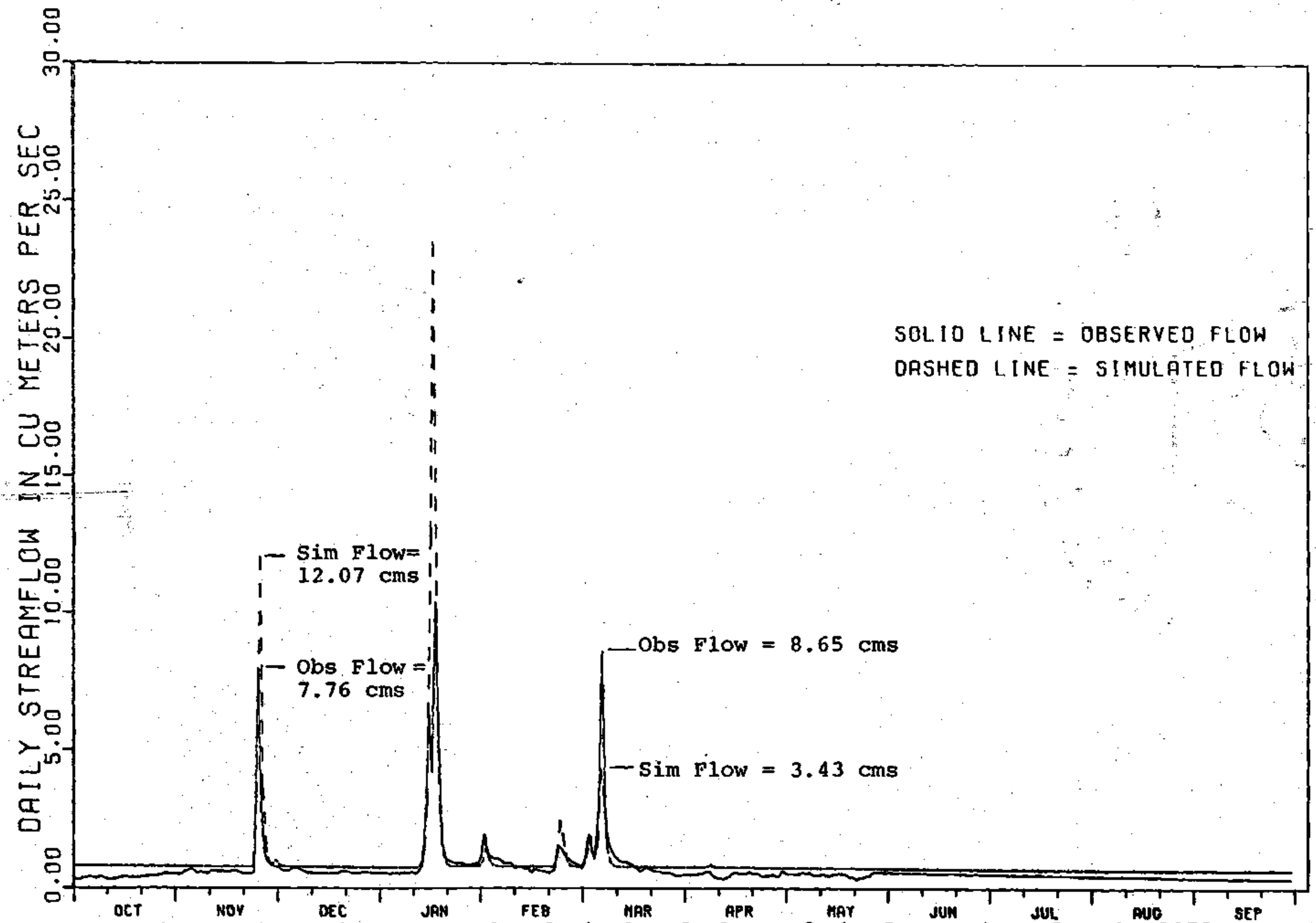


Figure 27. Daily Observed and Simulated Flows of the Zerqa River for the 1973 Water Year.

on January 10. The model, of course, did not respond to these small storms. However, the peak discharge of 22.80 cubic meters per second, recorded on March 23, was well predicted. The value of the simulated peak was 17.00 cubic meters per second. The weighted rainfall computed for this event was 28.00 millimeters. The two storm events of January 21-23, 1970 and March 9-11, 1970 were compared (see Figure 24). Although these two storms were similar in magnitude, a peak of 2.94 cubic meters per second and a peak of 12.20 cubic meters per second were recorded on January 23 and March 12, 1970. The simulated peaks were 6.03 and 4.55 cubic meters per second. The other example is in the 1972 water year (see Figure 26). The model successfully predicted the majority of the recorded peak flows, with the exception of the one recorded on April 9, 1972. The peak discharge recorded was 20.300 cubic meters per second. The weighted rainfall for this event is 2.11 millimeters on April 9 and 3.83 millimeters on April 10. The predicted flow was 1.033 cubic meters per second. A peak flow of 1.66 cubic meters per second was recorded on March 17, 1972. The weighted rainfall is 3.18 millimeters on March 15 and 15.61 millimeters on March 16. The second peak recorded on March 21 was 11.20 cubic meters per second. The weighted rainfall for this event is 5.36 and 10.26 millimeters on March 20-21, 1972. The predicted peak were 6.08 and 5.73 cubic meters per second. Finally, a comparison was made between two recorded peaks in the 1973 water year (see Figure 27). A peak of only 10.40 cubic meters per second was recorded on January 17, 1973. A major storm event occurred during the period of January 12-16. The weighted rainfall is 4.45, 5.81, 15.37, 17.86, and 4.16 millimeters. Meanwhile, a rainfall of 11.55 millimeters on March 6, 1973 produced a peak discharge of 8.65 cubic meters. per second on March 8. The model responded to the first storm and predicted a peak flow of 23.53 cubic meters per second on January 16 and predicted a peak flow of 4.36 cubic meters per second on March 7, 1973.

Although the rainfall stations network for this particular watershed is dense (40 square miles per station), two conclusions can be made in regard to the flood flows. The storms which caused the peaks mentioned earlier were very intense over small areas in the watershed and thus were not captured by the rainfall gages. The second conclusion is that the quality of either the rainfall or streamflow data is questionable.

Statistical analyses were performed on the predicted daily flows for the 5-years of record. The sum of the squared errors was 8.5690 square millimeters. The squared error of only one simulated flow was large enough to reduce this value by about 60 percent as illustrated in the following example: The observed streamflow hydrograph during the period from April 12-17, 1971 was 2.11, 107.00, 54.70, 41.70, 29.80 and 18.60 cubic meters per second. The model prediction was 4.66, 26.79, 61.03, 37.03, 27.25, and 15.92 cubic meters per second. The squared error of the simulated flow on April 13, 1971 was 4.946 square millimeters. The standard error of daily prediction, excluding some of the flood flows in the 5-year of record, was 48 percent. The sum of the absolute value of the errors was 29.0841 millimeters which corresponds to an average absolute value of the simulation error of 40 percent.

The monthly observed and simulated flows for the period 1968/1969-1972/1973 are listed in Table 13. The simulated monthly flows are plotted versus the observed monthly flows in Figure 28. The equal value line for the monthly flows is also plotted. The standard error of the predicted monthly flows for the simulation period was 42 percent. This was largely dependent on the simulated peak flow errors. The average absolute value of the prediction error was 31 percent.

Table 14 lists the monthly observed and simulated flows resulting from utilization of the sum of the squares of the error logarithms of the flows as a criterion of goodness of fit. The observed and the predicted monthly flows and their equal value lines are plotted in Figure 29. Statistical analyses were performed on the monthly simulated flows. The standard error of prediction was 49 percent and the average absolute value of the monthly simulated flows error was 38 percent. It can be concluded, after examining the monthly flows in Table 13 and Table 14, that no preference can be made in selecting between the two goodness of fit criteria. However,

Table 13. Monthly Observed and Simulated Flows of the Zerqa River for the 1969-1973 Water Years Utilizing the Sum of the Absolute Value of the Errors as a Goodness of Fit Criteria (Values are in Millimeters).

	1969 W. Y.		1970 W. Y.		1971 W. Y.		1972 W. Y.		1973 W. Y.	
Month	Obs	Sim	Obs	Sim	Obs	Sim	Obs	Sim	Obs	Sim
Oct	0.79	1.01	1.02	0.88	0.85	0.67	0.56	0.65	0.35	0.71
Nov	0.97	0.97	1.05	0.83	0.90	0.64	0.71	0.69	0.79	1.16
Dec	1.30	1.13	1.09	0.82	1.12	0.79	2.44	2.61	0.51	0.68
Jan	2.11	2.50	1.92	1.38	1.75	0.77	1.29	0.90	1.36	2.02
Feb	2.03	1.04	1.26	0.85	0.89	0.64	1.64	1.35	0.72	0.75
Mar	9.07	7.81	2.51	1.76	1.15	0.89	1.53	1.30	1.06	0.96
Apr	2.07	1.98	1.18	0.78	7.76	5.56	1.41	0.86	0.41	0.65
May	1.52	1.06	1.03	0.78	0.38	0.76	0.35	0.83	0.44	0.65
Jun	1.04	0.95	0.95	0.73	0.25	0.72	0.20	0.77	0.46	0.61
Jul	0.85	0.96	0.84	0.73	0.22	0.72	0.25	0.77	0.42	0.61
Aug	0.67	0.93	1.32	0.71	0.19	0.70	0.36	0.75	0.37	0.59
Sep	0.87	0.87	1.39	0.67	0.27	0.65	0.35	0.70	0.30	0.56
Annual	23.29	21.21	15.56	10.92	15.73	13.51	11.09	12.18	7.10	9.95

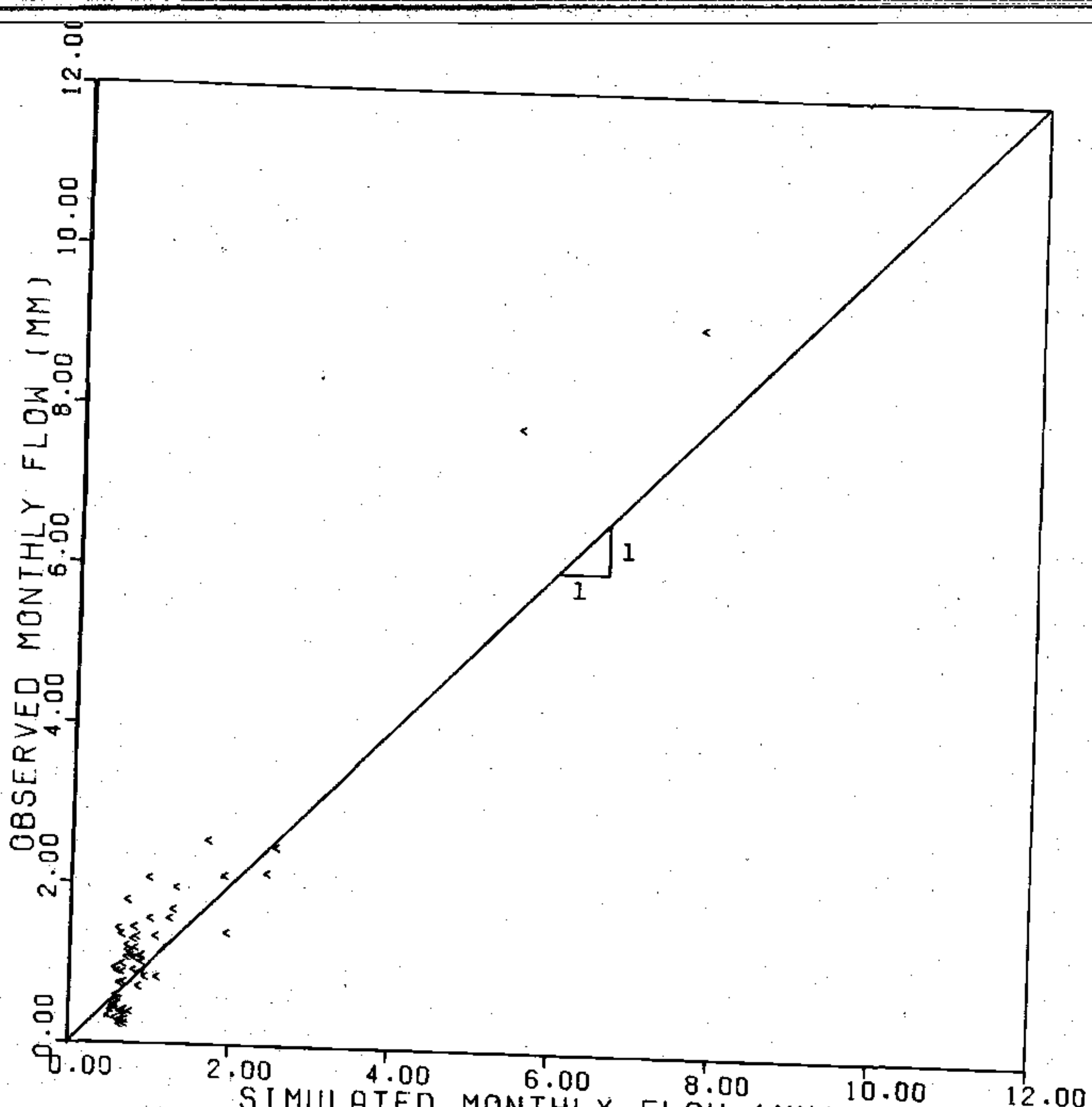


Figure 28. Scatter Diagram for the Simulation Results for the Zerqa River Monthly Streamflows of the 1969-1973 Water Years Utilizing the Sum of the Absolute Errors as a Goodness of Fit Criteria

Table 14. Monthly Observed and Simulated Flows of the Zerqa River for the 1969-1973 Water Years Utilizing the Sum of the Squared Error of the Logarithms of Flows as a Goodness of Fit Criteria (Values are in Millimeters).

	1969 W. Y.		1970 W. Y.		1971 W. Y.		1972 W. Y.		1973 W. Y.	
Month	Obs	Sim	Obs	Sim	Obs	Sim	Obs	Sim	Obs	Sim
Oct	0.79	1.01	1.02	0.89	0.85	0.71	0.56	0.78	0.35	0.86
Nov	0.97	0.98	1.05	0.84	0.90	0.69	0.71	0.83	0.79	1.47
Dec	1.30	1.20	1.09	0.83	1.12	0.91	2.44	3.43	0.51	0.84
Jan	2.11	3.02	1.92	1.58	1.75	0.89	1.29	1.84	1.36	2.60
Feb	2.03	1.18	1.26	0.96	0.89	0.73	1.64	3.74	0.72	0.99
Mar	9.07	8.03	2.51	2.22	1.15	1.06	1.53	2.89	1.06	1.26
Apr	2.07	2.44	1.18	0.84	7.76	6.22	1.41	1.45	0.41	0.85
May	1.52	1.17	1.03	0.83	0.38	0.91	0.35	1.01	0.44	0.84
Jun	1.04	0.96	0.95	0.78	0.25	0.85	0.20	0.94	0.46	0.79
Jul	0.85	0.96	0.84	0.78	0.22	0.85	0.25	0.94	0.42	0.79
Aug	0.67	0.93	1.32	0.76	0.19	0.83	0.36	0.92	0.37	0.77
Sep	0.87	0.88	1.39	0.71	0.27	0.78	0.35	0.86	0.30	0.72
Annual	23.29	22.76	15.56	12.02	15.73	15.43	11.09	19.63	7.19	12.78

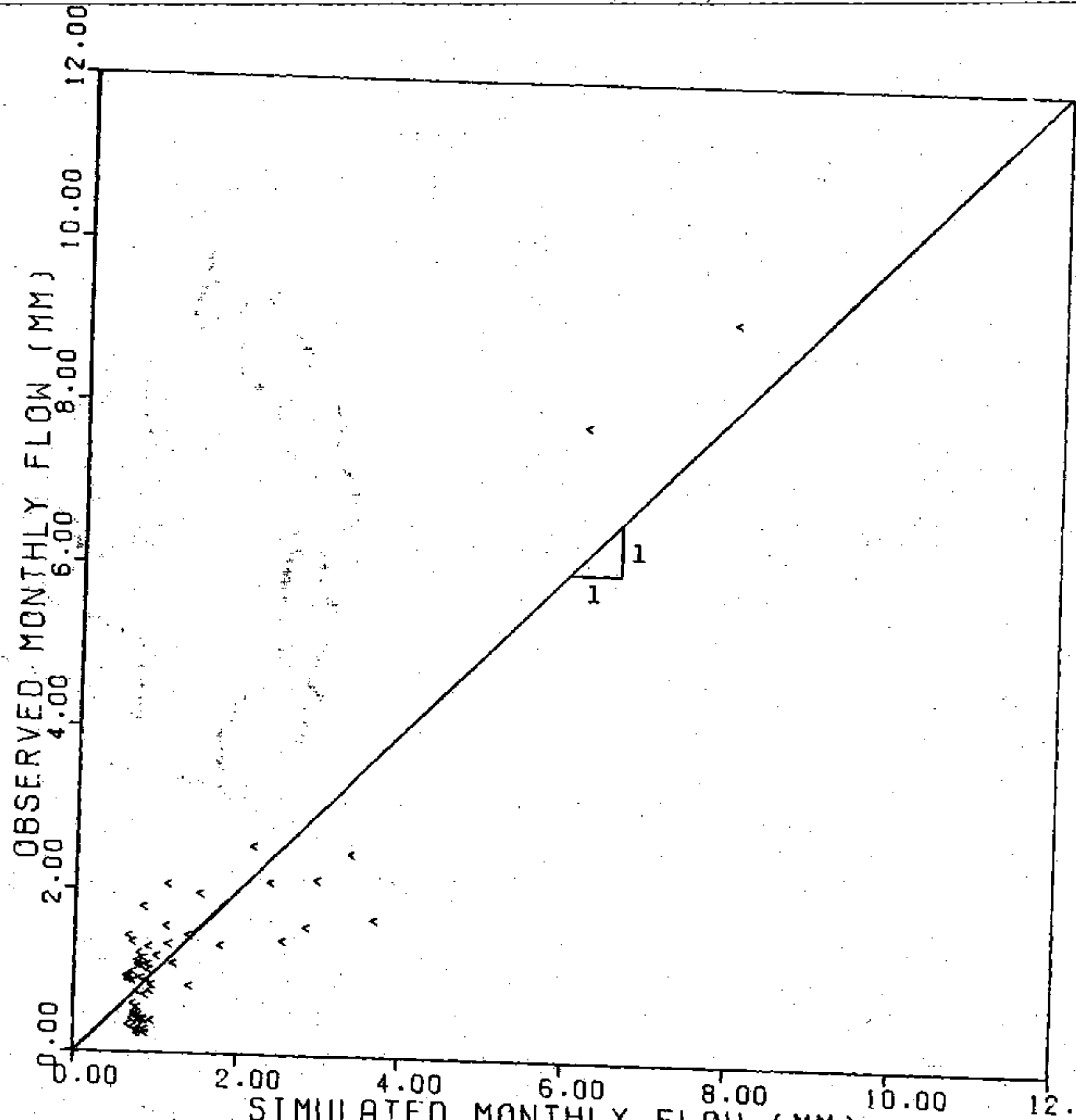


Figure 29. Scatter Diagram for the Simulation Results for the Zerqa River Monthly Streamflow of the 1969-1973 Water Years Utilizing the Sum of the Squared Errors of the Logarithms of Flows as a Goodness of Fit Criteria.

if the computed standard error of prediction or the computed average absolute value of the prediction error is used as a measure of comparing the two criteria, the sum of the absolute errors objective function as a goodness of fit criterion is slightly preferable.

The annual simulated flows listed in Table 13 indicate that the model undersimulated the flows of the 1969, 1970 and 1971 water years. The annual flows of the 1972 and the 1973 water years were overestimated. The apparent data error of the 1970 streamflow, especially in January and March, was partly responsible for the gross undersimulation. The quality of data of the 1973 water year, as previously discussed, and the possible flow diversion, beginning in March, contributed to the overprediction of the annual flow. The standard error of prediction of the calibrated 1969 water year was 9 percent; that for the period of simulation was 18 percent. The standard error was reduced to 11 percent when the annual flows of the 1970 and the 1973 water years were excluded.

Seil Zerqa Streamflow Simulation

The available streamflow record for this Seil consists of two years of streamflow (1972 and 1973 water years) measured at the gage site near the town of Sukhna. The drainage area of the basin is about 652 square kilometers. The weighted rainfall over the basin was computed utilizing the rainfall record of five stations for the 1972 water year and the rainfall record of four stations for the 1973 water year. Pan evaporation measurements of King Hussein Nursery Evaporation Station near Amman were also used.

The model was applied, with the optimization option, to simulate the 1972 water year streamflow. Table 15 lists the final values of the optimized parameters. The parameters stabilized and have reasonable and meaningful values. The value of the surface runoff routing parameter, FSRO, is 0.145. This value indicates that the daily simulated surface runoff was 14.5 percent of the generated surface runoff volume. The surface runoff in the following days was simulated by depleting the remaining 85.5 percent. The optimized FSRO parameter for the Zerqa River watershed had the smae value as for the smaller Seil Zerqa watershed. A larger watershed, with a longer length of travel should yield a smaller portion of the surface runoff volume reaching the gage site.

The statistical analysis performed in the last iteration of the optimization run yielded a correlation coefficient of the daily flows of 0.9201. The regression line slope was 0.9152 and its intercept was 0.0078. Daily observed and simulated flows are plotted in Figure 30. The model was successful in simulating the high peaks and low flows with the exception of the observed flows in March and April. The observed flows during this period seem to be questionable. For example, the weighted rainfall on March 16, 1972 was 16.41 mm. The observed peak flow was 1.67 cubic meters per

Table 15. List of the Fixed Parameter Values and the Initial and Final Values of the Optimized Parameters for the Seil Zerqa Watershed.

THE FOLLOWING IS THE FIXED AND INITIAL PARAMETER VALUES

PARAMETER	BSMI	BGWR	NCEPT	SQKM	FROK	SGWK	PGWK	SROK	PIMP	TRLOS
FIXED VALUE	20.000	2.700	4.030	652.000	.300	.975	.939	.225	0.000	0.000

PARAMETER	FMAX	FMIN	ALFN	AHORD	BHORP	FSRO	REXP	BHORD	EPAR	DLOSS
INITIAL VALUE	420.000	30.000	.130	50.000	10.000	.103	1.000	90.000	.500	0.000
UPPER LIMIT	610.000	60.000	.430	100.000	50.000	.150	4.000	200.000	1.000	.000
LOWER LIMIT	300.000	10.000	.050	20.000	5.000	.100	1.000	60.000	.500	0.000
INCREMENT	5.000	1.000	.025	1.000	1.000	.005	.050	1.000	.025	.025

THE FOLLOWING IS THE FINAL OPTIMIZATION RESULTS

PARAMETER	FMAX	FMIN	ALFN	AHORD	BHORP	FSRO	REXP	BHORD	EPAR	DLOSS
BEST VALUE	315.000	59.000	.230	59.000	16.000	.145	1.500	129.000	.525	.450

STATISTICS	EXPA	EXPB	ERROR	SSERR	SSLOG	ABSV	OBFN	CCOF	SLOPE	YINT
	1.0005	0.0000	5.1386	3.1545	25.5936	15.2892	15.2892	.9261	.9152	.0878

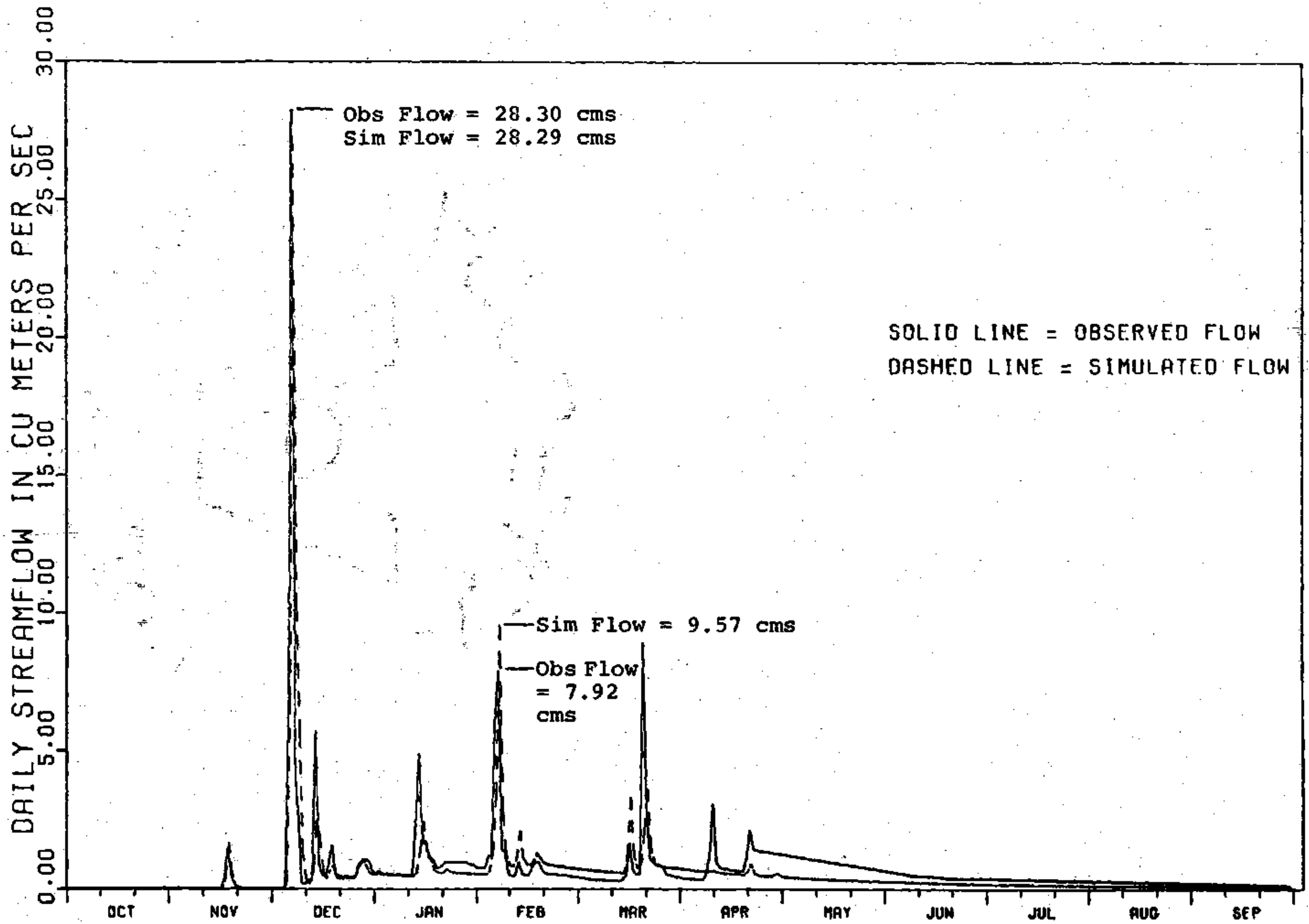


Figure 30. Daily Observed and Simulated Flows of Seil Zerqa for the 1972 Water Year.

second. The simulated peak was 3.34 cubic meters per second. Meanwhile, the weighted rainfall on April 10 was 4.67 mm. The observed peak was 3.12 cubic meters per second and the simulated peak was 0.69 cubic meters per second. Finally, a peak flow of 8.96 cubic meters per second was observed on March 21. The weighted rainfall on March 19-22 was 2.72, 6.51, 8.90, and 1.96 mm. The model predicted a flow of 2.05 cubic meters per second on March 21 and a peak flow of 3.65 cubic meters per second on March 22. Other examples can be seen by examining the observed hydrograph beginning April 20. The observed base flow was 0.65 cubic meter per second on April 22. The weighted rainfall was 7.72 mm in the previous day. The shape of the base flow recession curve would indicate that moisture is entering the groundwater from somewhere. The above observed data greatly contributed to the simulation error. The sum of the squared errors was 3.15 square millimeters and the sum of the absolute value of the simulated flows errors was 15.29 mm. The average absolute value of the daily simulation error was 45 percent. The large value of the error is mainly caused by the shape of the recession curve and by the questionable observed peak flows in March and April.

The observed and the simulated monthly flows are plotted in Figure 31. A standard error of prediction of 37 percent was achieved. The deviation between the observed.

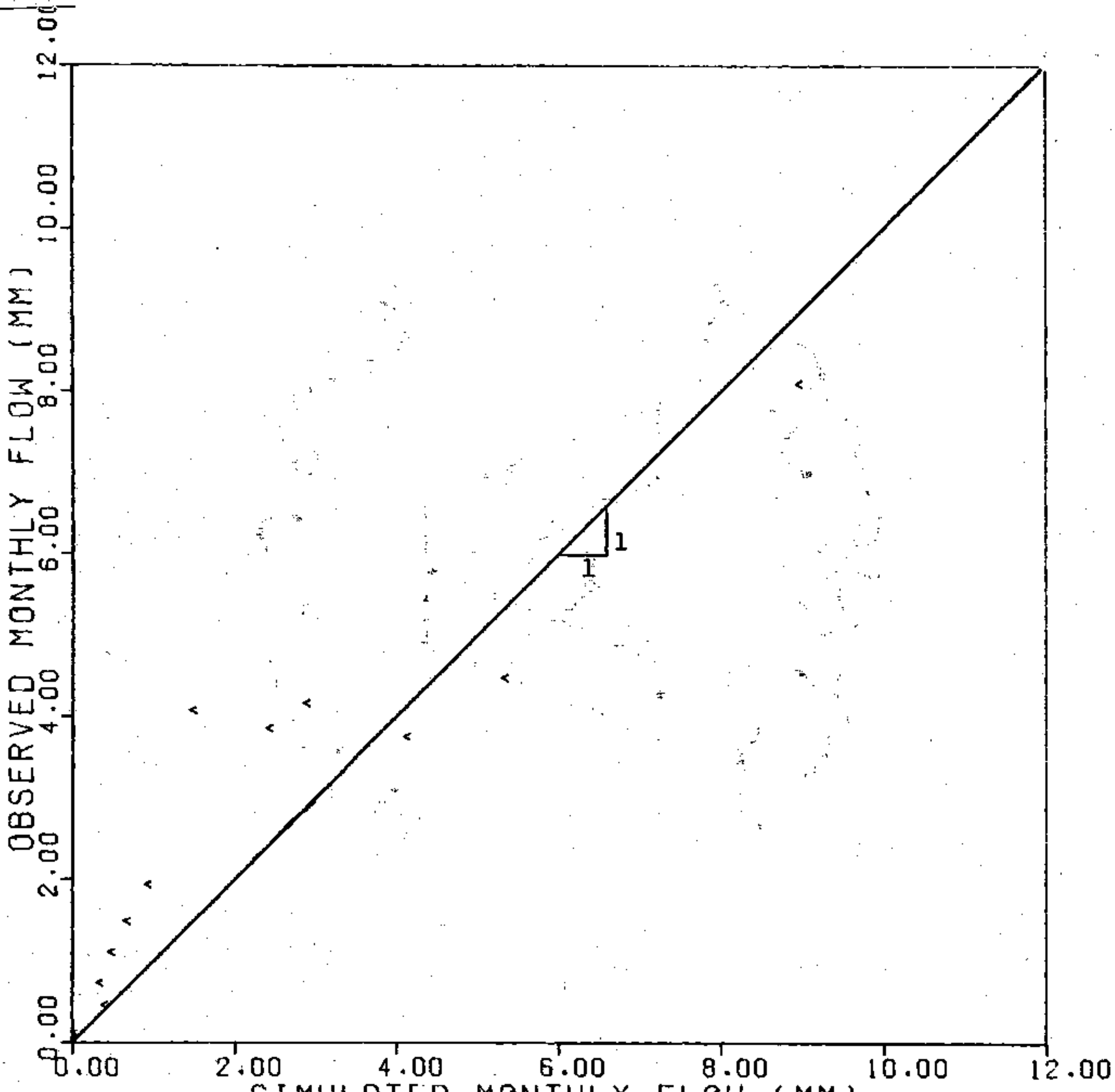


Figure 31. Scatter Diagram for the Simulation Results for Seil Zerqa Monthly Streamflow of the 1972 Water Year.

and the simulated flows for the period from April until September are responsible for the relatively high standard error. The standard error of simulation of 22 percent was achieved when the low flows, beginning in April, were excluded.

The optimized parameter values were used to simulate the streamflow of the 1973 water year as shown in Figure 32. Streamflow data for this year is of poor quality. It is apparent that a peak discharge in November was not recorded. All rainfall stations recorded more than 28.00 millimeters of rain. The model predicted a peak discharge of 5.82 cubic meters per second on November 25. The same can be said about the apparent missing peak flow in early March. A prime example is during the period of January 12-16, 1973. A major storm event occurred during this period. The weighted rainfall was 4.9, 16.34, 15.40, 24.03 and 2.73 millimeters. The observed peak flow of 8.92 cubic meters per second was recorded on January 17. The model predicted for this major event a peak flow of 25.84 cubic meters per second on January 16. Furthermore, low flows data is questionable. The observed base flow on February 26 was 0.74 cubic meter per second. The observed base flow after the March storm sharply dropped to 0.34 cubic meter per second.

The observed and the simulated monthly flows of the 1972-1973 water years are plotted in Figure 33. A wide scattering of the flows is expected. Table 16 lists the monthly observed and simulated flows for the two year period.

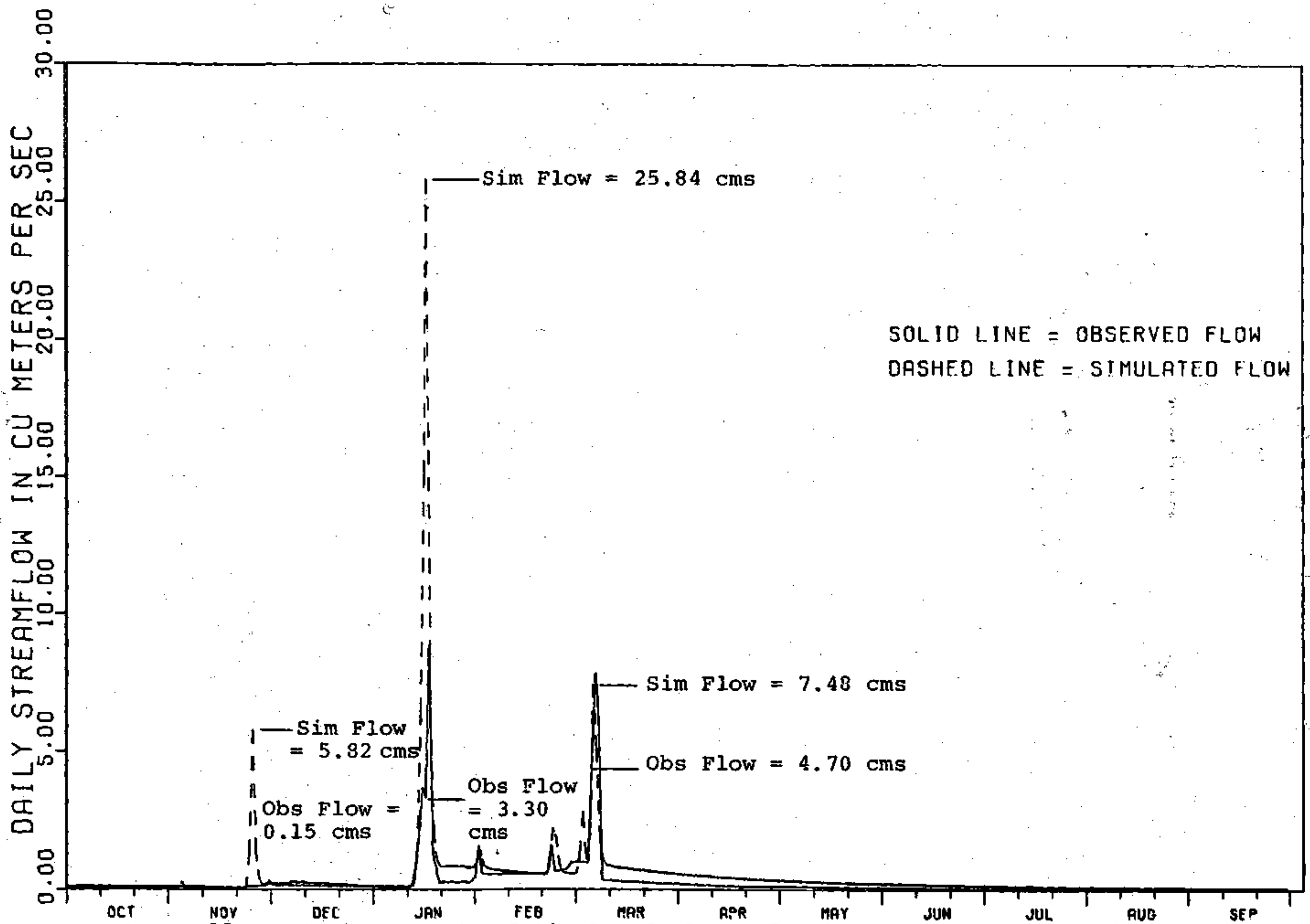


Figure 32. Daily Observed and Simulated Flows of Seil Zerqa for the 1973 Water Year.

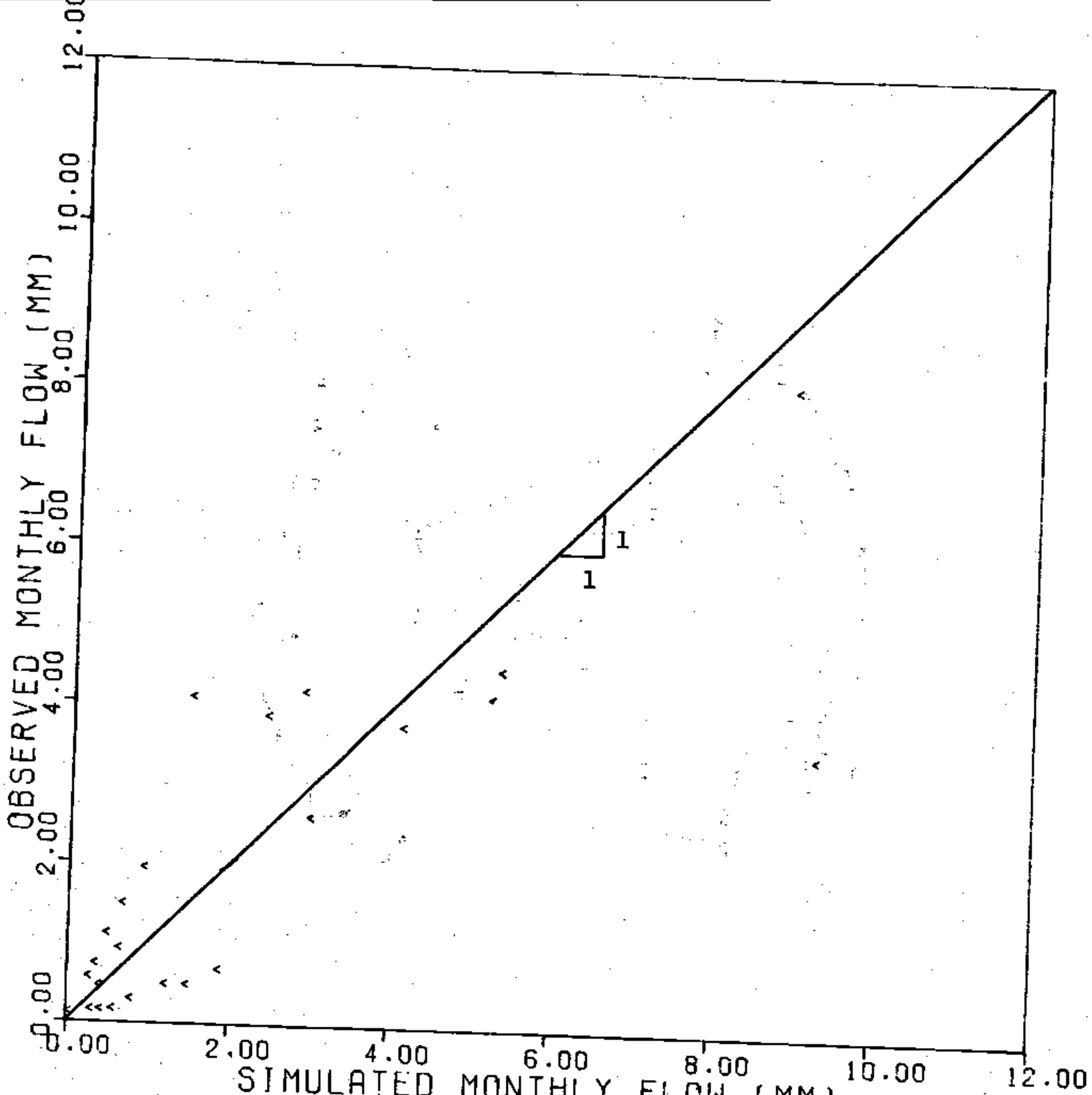


Figure 33. Scatter Diagram for the Simulation Results for Seil Zerqa Monthly Streamflow of the 1972-1973 Water Years.

Table 16. Monthly Observed and Simulated Flows of Seil Zerqa for the 1972-1973 Water Years (Values are in Millimeters).

	1972 Water Year		1973 Water Year	
Month	Obs	Sim	Obs	Sim
Oct	0.08	0.08	0.53	0.32
Nov	0.42	0.45	0.45	1.54
Dec	8.06	9.01	0.89	0.69
Jan	4.13	2.94	3.45	9.34
Feb	4.45	5.40	2.56	3.04
Mar	3.72	4.19	4.10	5.29
Apr	3.82	2.48	0.64	1.93
May	4.04	1.54	0.45	1.27
Jun	1.90	0.98	0.26	0.84
Jul	1.45	0.72	0.31	0.62
Aug	1.07	0.53	0.12	0.47
Sep	0.69	0.39	0.12	0.35
Annual	33.83	28.71	13.70	25.70

Statistical analyses were performed on the flows. The standard error of prediction was computed, and value of 76 percent was achieved for the two year period. The high value of the standard error indicates the effect of the poor quality of the streamflow data for this period. The missing peak flows and the sharp drop in the base flow of the 1973 water year greatly contribute to the gross error of the annual flow.

CHAPTER V

CONCLUSION AND RECOMMENDATIONS

The model was successful in simulating daily flows except where the observed streamflow and precipitation values are questionable. The model gave relatively better results in reproducing low flows than flood flows. Streamflow simulation was more successful on a monthly basis than a daily basis.

Comparison between observed and simulated flows, especially during the summer months, suggests that man-made activities such as flow diversions occurred during this period. Although this conclusion cannot be validated due to the lack of diversion data, flow diversion for irrigation purposes is commonly practiced in the area.

The model's component functions seemed to represent the basic hydrologic elements of a semi-arid region such as Jordan. Evaporation from the A Horizon soil takes place at a rapid rate due to the shallowness of the soil and its limited storage capacity. Evaporation dries this layer and forms a hard layer in the A Horizon soil. This causes evaporation from B Horizon soil to occur at a reduced rate. The location of the water table at a greater depth restricts further evaporation from the groundwater storage reservoir. The functions developed in this study in an attempt to estimate evaporation from the soils added a new feature to the model.

Examination of the observed streamflow data indicated the variability of base flow recession. An attempt was made to develop an equation to estimate the base flow recession constant as a function of groundwater storage in order to simulate base flow. A close reproduction of Zerqa River low flows was achieved. Although reproduction of Seil River low flows was not achieved with the same degree of accuracy as Zerqa River low flows simulation, for reasons previously mentioned, base flow modeling is another element featured in the Jordan watershed model.

The separation of the soil moisture storage into A Horizon and B Horizon compartments allows flexibility in modeling various hydrologic processes. Modeling of the top soil, which forms a dry stratum over the B Horizon, provides a shield against progressive evaporation from the deeper soils. Simulation results indicated no interflow. The evaporation rate is faster than the rate of filling A Horizon and thus does not allow the A Horizon storage capacity to be exceeded.

The permeability of the lower soil is well simulated by the model. This is evident from the low value of the parameter BHORP which describes the rate of drainage from A Horizon to B Horizon. Accordingly, moisture movement to B Horizon is slow and thus allows moisture to remain in A Horizon storage to satisfy the evaporation demands. This phenomenon explains the small quantity of simulated groundwater recharge.

The weak point of the model is in modeling the surface runoff routing. This is apparent from the value of the FSRO parameter. Obviously, the larger the watershed, the smaller the FSRO. A value of 0.145 was obtained as a result of the optimization runs for both the Zerqa River watershed (3116 km^2) and the Seil Zerqa watershed (652 km^2). A value greater than 0.145 for the Seil Zerqa watershed is more reasonable.

For the two basins for which results are presented in this study, the standard errors of prediction and the average absolute value of the simulation errors achieved indicate that selection of the absolute value of errors criterion, as a parameter fitting procedure, yields slightly better simulation results. The domination of low flows in the streamflow record suggests utilizing the average absolute value of the simulation error rather than the standard error of prediction as a statistical tool for measuring the level of accuracy of the simulation results. The standard error of prediction is sensitive to the high flow errors and tends to minimize the effects of the low flows errors.

The Jordan Watershed Model helps to shed light on the hydrological behavior of the Zerqa River watershed. Inferences can be made by examining the moisture accounting performed on various components of the model. The ultimate purpose of these inferences is to attempt to gain a better understanding of the hydrologic cycle components. In areas, such as Jordan, where detailed hydrological analyses have not been made, the model becomes a useful tool to help formulate a water resources policy for the country. The main advantage in classifying the net moisture into surface runoff, recharge, etc. is to aid in planning and developing the various portions of water resources. An example of such planning would be to restrict excessive groundwater pumping. Planning water supply and irrigation projects can be more effective if one knows how much water to expect.

The analysis made utilizing the model is considered an initial attempt to study the hydrologic cycle of Jordan based on approximate mathematical representations of the major hydrologic processes. The Zerqa River watershed simulation results were utilized to gain a better understanding of the major elements of the hydrologic cycle. Table 17 gives an annual summary of various model component responses, namely surface runoff, groundwater recharge, evaporation, deep losses, and soil moisture storage. The amount of moisture in each component is expressed in millimeters over the basin and as a percentage of annual rainfall. Evaporation accounts for the major percentage of rainfall. In a relatively wet year, such as the 1969 water year, 84.50 percent of the total rainfall is consumed by evaporation. Soil moisture storage increased by 15 mm. The percentage of surface runoff is only 3.37 percent. Recharge occurred and accounted for 3.35 percent of total rainfall. The moisture

Table 17. Summary of Simulated Surface Runoff, Recharge, Evaporation, Losses and Change in Soil Moisture of the Zerqa River Watershed (Values are in Millimeters).

Water Year	Rainfall	Surface Runoff (Percent)	Recharge (Percent)	Evaporation (Percent)	Losses (Percent)	Change in Soil Moisture
1969	249.52	8.41 (3.37)	8.37 (3.35)	210.85 (84.50)	6.85 (2.75)	+15.04 (6.03)
1970	171.03	1.68 (0.98)	2.54 (1.49)	169.43 (99.06)	2.07 (1.21)	-4.69 (-2.74)
1971	245.87	5.61 (2.28)	7.45 (3.03)	219.97 (89.47)	6.10 (2.48)	+6.74 (2.74)
1972	241.03	3.19 (1.32)	10.67 (4.43)	221.55 (91.92)	8.73 (3.62)	-3.12 (-1.29)
1973	147.40	2.23 (1.51)	2.88 (1.96)	144.28 (97.88)	2.36 (1.60)	-4.35 (-2.95)
Average	210.97	4.22 (2.00)	6.38 (3.02)	193.22 (91.59)	5.22 (2.47)	+1.93 (0.92)

which percolated to deep aquifers, seeps, and springs is on the order of 2.75 percent. The situation in a drought year, such as the 1970 water year, is more severe. A total of 169.43 mm evaporated. Evaporation was so excessive that it caused a soil moisture deficiency of 4.69 mm. When the five years were combined, the average evaporation was 91.59 percent. Total runoff accounts for 5.02 percent and an estimated 2.47 percent goes to deep aquifers. The soil moisture storage was increased, on the average, by 1.93 mm.

The observed flows of the 1969 water year are better matched than the other four years. If we consider the simulation results of this year to be good, then these percentages would represent reasonable values. These percentages approximately conform with the findings of the British consultants, Sir MacDonald and Partners. As discussed in Chapter I, soil moisture evaporation was estimated ans was found to account for 88 percent of total rainfall. The total runoff was estimated by subtracting the evaporation from the total rainfall. It can be concluded from Table 17 that total runoff (surface runoff and recharge) accounts for a portion of the net moisture after evaporation takes place. The consultants concluded in their analysis of five years of records (1959-1964) that no recharge was found to take place where average precipitation is less than 200 millimeters. During the drought year 1973 average rainfall was 147.40 millimters. The increase of base flow during January and February of that year, as can be seen by examining the observed streamflows, indicates that groundwater was recharged during this period. The successful simulation of the observed base flow, especially during February, implies that groundwater recharge has been simulated, and is in agreement with the observations. The model predicted groundwater recharge of about two percent of the rainfall.

Mitchell[4] stated

> No evaluation of long term groundwater development can be undertaken without a reasonably accurate estimate of groundwater recharge. In more developed areas where considerable groundwater exploitation exists this information can be derived from a study of well and river hydrographs but in a developing country where such information is not available there is no ready alternative to an evaporation study to establish recharge conditions and determine the elements of basic hydrological equation $P = R + E + G$, where P = precipitation, R = storm runoff, E = evaporation from wet soil through plants or from the soil surface and G = change in soil moisture content.

The Jordan watershed model is an alternative to such an evaporation study and is a valuable tool in estimating the elements of the basic hydrological equation.

From the simulation results, the following recommendations are made.

1. The Natural Resource Authority of Jordan should put more emphasis on the quality of data. Streamflow simulation is a useful tool in planning and developing water resources. The success of streamflow simulation models depends on the quality and quantity of observed data.

2. The model should undergo further calibrations in an attempt to revise the values of the constants in various functions when additional data becomes available. These values were determined from the limited available data.
3. It would be advantageous to calibrate the model on watersheds in other semi-arid regions. The Arab Center for the Studies of Arid Zones and Dry Lands has shown an interest in the outcome of this research. This will allow for further improvements of the model and wider applications.
4. It is apparent that surface runoff routing modeling requires further improvement. The watershed unit hydrograph, or the time-area histogram, can be utilized for this purpose. Introduction of two parameters to represent the portion of surface runoff volume that appears in the channel in the first, second, and third day is alternative to the above suggested methods.
5. Although the model produced good simulation results utilizing daily rainfall, performing the moisture accounting on an hourly basis would, without a doubt, improve the simulation result. This task is pending the availability of hourly rainfall.

APPENDIX I

JORDSM INPUT DATA REQUIREMENT

A. Weighted Rainfall

Program WTRAIN computes weighted rainfall over a basin. The program accepts daily rainfall data for a maximum of ten stations. Ten years of rainfall record is the maximum period.

Card No.	Program Location	(FORMAT) or Card Column	Variable Names and Description
1A	WTRAIN	(3I4)	NYEAR, BYEAR, IPCH
		1-4	NYEAR = The total number of years of rainfall record (max. 10-yrs)
		5-8	BYEAR = Beginning water year of record
		9-12	IPCH = A control variable used to determine if computed weighted rainfall to be punched on cards.
			IPCH = 0 No Punch
			IPCH = 1 Computer generates punched cards of weighted rainfall in 10 F8.2 format

Card No. 2A and 3A are repeated NYEAR times in sets for each water year. (Max. 10-sets).

Card No.	Program Location	(FORMAT) or Card Column	Variable Names and Description
2A	WTRAIN	(I4,3X, 10F7.0)	NST, (STWT(I), I = 1, NST)
		1-4	NST = Number of rainfall stations in a water year
		8-15 16-23 : 71-77	(STWT(I), I = 1, NST) Station weight for NST stations.

Card No.	Program Location	(FORMAT) or Card Column	Variable Names and Description
	Cards No. 3A are repeated NST times, one set for each station. (Max. 10-sets)		
3A	WTRAIN	10F8.2	(SRF(JST,I), I = 1, NNYR)
		1-8 7-16 . : 73-80	One water year of daily rainfall in mm (37 cards). JST is the current station number and NNYR is the number of days in a water year as determined by the Program.

B. Parameter Optimization and Streamflow Simulation

The Jordan Watershed Model Program is written on the CDC CYBER 74 Computer under the control of the Nos 1.3 operating system utilizing the FORTRAN extended compiler.

The Program JORDSM performs parameter optimization using Pattern Search technique. Ten parameters are optimized simultaneously. Streamflow simulation is performed automatically using the final values of the optimized parameters and other required input data. The program could also perform simulation analysis for a given set of parameters without optimization. The program uses the punched cards of weighted daily rainfall resulting from excuting Program WTRAIN. Rainfall records of one station can also be used if desired. Daily pan evaporation and observed streamflow data for the desired period should be coded and punched.

Listed below are the variables and other information for setting up input to the program to perform parameter optimization and streamflow simulation.

Card No.	Program Location	(FORMAT) or Card Column	Variable Names and Description
1B	JORDSM	(I4)	NSHED
		1-4	NSHED = The number of watershed to be run.
2B	JORDSM	(10A8)	TITLE
		1-80	TITLE = The name and location of the watershed

Card No.	Program Location	(FORMAT) or Card Column	Variable Names and Description
3B	JORDSM	(9I4)	NOBSY, NEVP, IOPT, IROP, IPLOT, IPLOTL, ICPLOT, LOGS, NCARD
		1-4	NOBSY = A control variable used to determine if observed daily streamflow values are read in
			NOBSY = 0 No values are read in
			NOBSY = 1 Values are read in
		5-8	NEVP = A control variable used to determine if pan evaporation data is read for each water year
			NEVP = 0 Read daily pan evaporation measurements only for the first year of simulation. This option is used when pan evaporation measurements are not available for the entire period of simulation.
			NEVP = 1 Read daily pan evaporation measurements for each year.
		9-12	IOPT = A control variable used to determine if parameter optimization to be performed.
			IOPT = 0 No optimization
			IOPT = 1 Program optimizes ten parameters and makes simulation run
		13-16	IROP = A control variable used to determine if detailed optimization output is desired
			IROP = 0 No detailed optimization output is printed. Only the final values of optimized parameters and pertinent statistics are printed.

Card No.	Program Location	(FORMAT) or Card Column	Variable Names and Description
			IROP = 1 Program lists values of optimized parameters and other information for each iteration.
		17-20	IPLOT = A control variable used to determine if arithmatic scale plot of the simulated and observed flows is desired. The plotting scale is determined in Card 18B.
			IPLOT = 0 No plotting
			IPLOT = 1 Provide plots
		21-24	IPLOTL = A control variable used to determine if log scale plot of simulated and observed flows is desired. The plotting scale is automatically determined according to the drainage area of basins.
			IPLOTL = 0 No plotting
			IPLOTL = 1 Provide plots
		25-28	ICPLOT = A control variable used to determine if CALCOMP plotting is desired.
			ICPLOT = 0 No plotting
			ICPLOT = 1 Provide CALCOMP plots
		29-32	LOGS = A control variable used to determine what type of CALCOMP plotting is desired
			LOGS = 0 Provide arithmatic scale CALCOMP plots
			LOGS = 1 Provide logarithmic scale CALCOMP plots

Card No.	Program Location	(FORMAT) or Card Column	Variable Names and Description
		33-36	NCARD = A control variable to determine if simulated daily streamflows are to be punched on cards.
			NCARD = 0 No punched cards are desired
			NCARD = 1 Punched cards are desired
4B	JORDSM	(2F8.0)	EXPA, EXPB Objective function exponents. Objective function is calculated when NOBSY = 1
		1-8	EXPA = Exponent of the numerator of the objective function
			EXPA = 0.0 The objective function to be calculated is the sum of the squared errors of the flow logarithms
			EXPA = 1.0 The objective function is the sum of the absolute value of the errors
			EXPA = 2 The objective function is the sum of squares of the daily errors
		9-16	EXPB = Exponent of the denominator of the objective function. Use a value of zero for EXPB in all cases.

Card No. 5B is needed when NCARD = 1 (see card No. 3B)

Card No.	Program Location	(FORMAT) or Card Column	Variable Names and Description
5B	JORDSM	A2	TITE
		1-2	TITE = Two-character description to be punched on each punched card for identification purposes.

Card No.	Program Location	(FORMAT) or Card Column	Variable Names and Description

Card No. 6B, Card No. 7B, Card No. 8B, Card No. 9B, and Card No. 10B are needed if IOPT = 1, i.e., when parameters optimization is desired.

Card No.	Program Location	(FORMAT) or Card Column	Variable Names and Description
6B	JORDSM	(4I4)	NPAR, MXRES, MXRUN, NDLTA
		1-4	NPAR = Number of parameters to be optimized. In JORDSM, ten parameters are optimized simultaneously. User should input NPAR = 10
		5-8	MXRES = Maximum number of resolutions in the optimization process. A reasonable value of MXRES varies from 1 to 4.
		9-12	MXRUN = Maximum number of iteration in the optimization process.
		13-16	NDLTA = A code specifying the type of increment, DELTA, to each parameter in the optimization process.
			NDLTA = 0 DELTA is a fixed quantity
			NDLTA = 1 DELTA is a fraction of the last accepted parameter value
7B	JORDSM	(10F8.0)	(PRPAR(I), I = 1, NPAR) Initial value for each optimized parameter.
		1-8	PRPAR (1) = FMAX
		9-16	PRPAR (2) = FMIN
		17-24	PRPAR (3) = ALFN
		25-32	PRPAR (4) = AHORD
		33-40	PRPAR (5) = BHORP
		41-48	PRPAR (6) = FSRO
		49-56	PRPAR (7) = REXP
		57-64	PRPAR (8) = BHORD
		65-72	PRPAR (9) = EPAR
		73-80	PRPAR(10) = DLOSS

Refer to Card No. 11B for parameters definition.

Card No.	Program Location	(FORMAT) or Card Column	Variable Names and Description
8B	JORDSM	(10F8.0)	(UPPER(I), I = 1, NPAR) Upper limit value for each optimized parameter.
		1-8	UPPER (1) = Upper limit value of FMAX
		9-16 ⋮	UPPER (2) = Upper limit value of FMIN
		73-80	UPPER(10) = Upper limit value of DLOSS
9B	JORDSM	(10F8.0)	(LOWER(I), I = 1, NPAR) Lower limit value for each optimized parameter.
		1-8	LOWER (1) = Lower limit value of FMAX
		9-16 ⋮	LOWER (2) = Lower limit value of FMIN
		73-80	LOWER(10) = Lower limit value of DLOSS
10B	JORDSM	(10F8.0)	(DELTA(I), I = 1, NPAR) Increment, DELTA, value for each parameter.
		1-7	DELTA (1) = DELTA for FMAX
		8-16 ⋮	DELTA (2) = DELTA for FMIN
		73-80	DELTA(10) = DELTA for DLOSS

Card No. 11B and Card No. 12B are required if IOPT = 0, i.e., read model parameters if optimization is not desired.

Card No.	Program Location	(FORMAT) or Card Column	Variable Names and Description
11B	MODEL	(10F8.0)	FMAX, FMIN, ALFN, AHORD, BHORP, FSRO, REXP, BHORD, EPAR, DLOSS
		1-8	FMAX = Maximum point infiltration capacity, mm/day
		9-16	FMIN = Minimum infiltration capacity, mm/day

Card No.	Program Location	(FORMAT) or Card Column	Variable Names and Description
		17-24	ALFN = Infiltration function decay exponent.
		25-32	AHORD = Maximum storage capacity of A Horizon, mm.
		33-40	BHORP = Drainage function parameter, mm/day.
		41-48	FSRO = Surface runoff volume parameter.
		49-56	REXP = Recharge function decay exponent.
		57-64	BHORD = Maximum storage capacity of B Horizon, mm.
		65-72	EPAR = B Horizon evaporation reduction parameter
		73-80	DLOSS = Fraction of G.W. recharge lost to deep aquifers and springs.
12B	MODEL	(10F8.0)	BSMI, BGWR, SQKM, WCEPT, FORK, SGWK, PGWK, SROK, PIMP, TRLOS
		1-8	BSMI = Initial soil moisture in B Horizon, mm.
		9-16	BGWR = Initial groundwater reservoir storage, mm
		17-24	SQKM = Drainage area in sq. kilometers.
		25-32	WCEPT = Maximum depression storage capacity, mm.
		33-40	FROK = Interflow recession constant.
		41-48	SGWK = Minimum base flow recession constant.
		49-56	PGWK = Maximum base flow recession constant
		57-64	SROK = Surface runoff recession constant.

Card No.	Program Location	(FORMAT) or Card Column	Variable Names and Description
		65-72	PIMP = Impervious area fraction of total area
		73-80	TRLOS = Transmission losses in fraction.

Card 13B is required if IOPT = 1, i.e., when parameter optimization is desired.

13B	MODEL	(10F8.0)	(FPAR(I), I = 1, 10) Fixed values of parameters which are not optimized. Refer to Card No. 12B for parameters definition.
		1-8	FPAR (1) = BSMI
		9-16	FPAR (2) = BGWR
		17-24	FPAR (3) = SQKM
		25-32	FPAR (4) = WCEPT
		33-40	FPAR (5) = FROK
		41-48	FPAR (6) = SGWK
		49-56	FPAR (7) = PGWK
		57-64	FPAR (8) = SROK
		65-72	FPAR (9) = PIMP
		73-80	FPAR(10) = TRLOS
14B	MODEL	2I4	NYRS, BYEAR
		1-4	NYRS = The total number of water years to be simulated.
		5-8	BYEAR = The last two digit of the beginning water year of the simulation period.

The following cards 15B through 17B are repeated NYRS times in sets for each water year and read in blocks of 5-years (or fraction thereof). Each water year of pan evaporation measurements is followed by the corresponding water year of rainfall and streamflow.

Card No.	Program Location	(FORMAT) or Card Column	Variable Names and Description

Card No. 15B is needed only once if NEVP = 0. This option is required when the user desires to select one water year of pan evaporation measurement to represent the measurement of the entire period of simulation years.

15B	PANEVP	(10F8.0)	(ET(J, I), I = 1, NNYR)
		1-8	Pan evaporation measurement, in mm for one water year (37 cards).
		9-16 ⋮	NNYR is the number of days in water year as determined by the program
		73-80	
16B	MODEL	(10F8.0)	(RF(J, I), I = 1, NNYR)
		1-8	Daily rainfall in mm for one water year (37 cards).
		9-16 ⋮	
		73-80	

Card No. 17B is required if NOBSY = 1

17B	MODEL	(10F8.0)	(QDAY(J, I), I = 1, NNYR)
		1-8	Daily observed streamflow in cubic meters per seconds for one water
		9-16 ⋮	year (37 cards).
		73-80	

Card No. 18B is required if NOBSY = 1 and IPLOT = 1; it is repeated NYRS times in sets of 5 water years (or fraction thereof).

18B	PLOTA	F5.0	YMAXR
		1-5	YMAXR = Runoff plotting full scale used in the arithmatic plots. This option is useful to magnify low flows. If YMAXR = 0.0, the full scale is equal to the max. value in either observed or simulated flows.

APPENDIX II

COMPUTER OUTPUT DESCRIPTION

The following is a description of the optimization and simulation runs computer outputs for the Zerqa River and Seil Zerqa watersheds.

Optimization Run Output

The output begins with a list, for each year, of daily pan evaporation measurements, daily rainfall data, and observed streamflow data. The value of the fixed parameters and the initial values of the optimized parameters including their upper limit, lower limit, and the increments, DELTA's are listed. The program then performs the parameter optimization and lists in each run the parameter initial values and the present values of ten optimized parameters. The program lists the run number and the value of objective function associated with the present values of the parameter. The best value of the objective function prior to the present run is also printed. The result of the statistical analysis performed on the simulated flows, using the present parameter values, is printed. Description of each variable associated with the statistics output is given below:

EXPA - indicates the type of the objective function selected for the optimization run.

EXPB - the exponent of the denominator of the objective function equation.

ERROR - the arithmatic sum of the daily flow errors.

SSERR - the sum of the squared errors of the daily flows.

SSLOG - the sum of the squared errors of the logarithms of the daily flows

ABSV - the sum of the absolute value of the errors of the daily flows.

OBFN - the value of the selected objective function which has the value of SSERR or SSLOG or ABSV as determined by the value of EXPA.

CCOF - the correlation coefficient.

SLOPE - the slope of the regression line between the observed and the simulated daily flows being the observed flow the dependent variable.

YINT - the intercept of the regression line.

The computer saves in memory the final value of the optimized parameters and performs the streamflow simulation. The program prints daily moisture accounting table and summary for each month. The list below defines some of the variables associated with the moisture accounting tables.

PET - the estimated potential evapotranspiration computed by multiplying pan evaporation by the corresponding pan coefficient.

AET - the estimated actual evapotranspiration from depression storage, A Horizon and B Horizon soil moisture storages.

PSRO - surface runoff from impervious areas.

SURVOL - surface runoff volume.

SURES - moisture in surface runoff stroage.

SURO - rounted surface runoff.

IFVOL - interflow volume

IFRES - moisture in interflow storage.

IFRO - routed interflow

INFL - moisture infiltrated to A Horizon moisture storage.

DRAIN - moisture drained from A Horizon storage to B Horizon storage

RECHAR - net recharged moisture to the groundwater storage.

DLOSS - moisture leaving the B Horizon to deep aquifers, seep, springs, etc. (i.e., moisture lost to the groundwater storage).

PGWR - groundwater storage.

GWRK - base flow recession constant.

GWRO - routed base flow.

AHOR - moisture in A Horizon storage.

BHOR - moisture in B Horizon storage.

Finally, annual summary is printed. The final parameter values and a summary of the statistical analysis are given. The program prints the daily simulated streamflow table.

Simulation Run Output

The output begins with a list of the parameter values for the simulation period. Tables of pan evaporation measurements, rainfall and observed streamflow are printed. Daily moisture accounting for each month and annual summary are given for each water year. Finally, the Program performs statistical analysis for the entire period of simualtion and lists the results.

This Appendix contains the following computer print-outs:

1. Optimization Run Output for the Zerqa River watershed for the 1969 water year. Optimization iterations and monthly moisture accounting tables are omitted.
2. Simulation Run Output for the Zerqa River watershed for the period of 1969-1973. Daily moisture accounting tables are not included.
3. Optimization Run Output for Seil Zerqa watershed. The input variable IROP was set to be zero and thus caused the program to print only the optimization results and by-passing the optimization iterations printout.
4. Simulation Run Output for Seil Zerqa watershed for the period of 1972-1973.

PAN EVAPORATION FOR YEAR 1959 ZERQA RIVER STREAMFLOW SIMULATION VALUES IN MILLIMETERS

DAY	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	DAY
1	6.000	3.000	3.000	3.000	1.000	8.000	5.000	9.000	19.000	5.000	8.000	13.000	1
2	7.000	3.000	4.000	5.000	3.000	11.000	4.000	9.000	21.000	9.000	9.000	10.000	2
3	6.000	5.000	5.000	3.000	3.000	5.000	7.000	5.000	13.000	11.000	9.000	14.000	3
4	7.000	7.000	1.000	2.000	4.000	6.000	3.000	6.000	13.000	10.000	12.000	11.000	4
5	7.000	9.000	2.000	2.000	3.000	10.000	4.000	7.000	11.000	11.000	11.000	8.000	5
6	7.000	6.000	0.000	2.000	3.000	9.000	4.000	6.000	10.000	10.000	9.000	9.000	6
7	6.000	4.000	3.000	1.000	5.000	6.000	5.000	8.000	12.000	10.000	8.000	9.000	7
8	7.000	5.000	3.000	1.000	2.000	3.000	5.000	9.000	12.000	11.000	8.000	10.000	8
9	8.000	4.000	2.000	1.000	1.000	4.000	4.000	10.000	10.000	10.000	9.000	8.000	9
10	6.000	7.000	2.000	2.000	2.000	3.000	6.000	7.000	9.000	12.000	9.000	8.000	10
11	6.000	6.000	3.000	2.000	3.000	2.000	5.000	8.000	11.000	12.000	8.000	9.000	11
12	5.000	4.000	2.000	3.000	4.000	4.000	6.000	9.000	12.000	12.000	10.000	12.000	12
13	6.000	4.000	3.000	1.000	2.000	4.000	5.000	8.000	13.000	10.000	11.000	11.000	13
14	7.000	3.000	2.000	0.000	2.000	5.000	8.000	6.000	11.000	8.000	10.000	8.000	14
15	12.000	4.000	2.000	2.000	3.000	3.000	2.000	7.000	13.000	9.000	11.000	7.000	15
16	9.000	4.000	2.000	4.000	5.000	8.000	6.000	9.000	14.000	9.000	12.000	9.000	16
17	6.000	6.000	3.000	3.000	5.000	9.000	2.000	9.000	10.000	9.000	12.000	9.000	17
18	7.000	5.000	2.000	3.000	4.000	5.000	3.000	8.000	10.000	10.000	12.000	8.000	18
19	5.000	7.000	3.000	1.000	3.000	2.000	6.000	9.000	9.000	9.000	11.000	8.000	19
20	7.000	5.000	3.000	0.000	2.000	2.000	8.000	12.000	10.000	12.000	10.000	7.000	20
21	6.000	5.000	4.000	0.000	3.000	2.000	8.000	20.000	10.000	12.000	9.000	10.000	21
22	6.000	6.000	4.000	0.000	3.000	1.000	11.000	16.000	12.000	11.000	12.000	11.000	22
23	6.000	1.000	5.000	2.000	4.000	1.000	6.000	12.000	10.000	10.000	11.000	8.000	23
24	5.000	1.000	3.000	1.000	4.000	3.000	6.000	11.000	6.000	10.000	11.000	9.000	24
25	4.000	5.000	7.000	0.000	4.000	5.000	7.000	9.000	9.000	9.000	13.000	10.000	25
26	4.000	3.000	2.000	1.000	6.000	10.000	5.000	8.000	11.000	8.000	13.000	8.000	26
27	4.000	3.000	2.000	1.000	5.000	6.000	6.000	13.000	13.000	9.000	11.000	10.000	27
28	6.000	3.000	3.000	3.000	4.000	7.000	6.000	11.000	11.000	8.000	11.000	9.000	28
29	5.000	4.000	3.000	3.000	0.000	9.000	8.000	12.000	9.000	8.000	9.000	11.000	29
30	5.000	2.000	4.000	2.000	0.000	5.000	10.000	16.000	9.000	10.000	12.000	11.000	30
31	2.000	0.000	2.000	2.000	0.000	9.000	8.000	19.000	6.000	10.000	10.000	8.000	31
TOTAL	193.00	137.00	89.00	50.00	93.00	166.00	171.00	305.00	344.00	307.00	321.00	265.00	

TOTAL FOR WATER YEAR = 2456.00 MILLIMETERS

77/11/02 JORDAN CONTINUOUS DAILY STREAMFLOW SIMULATION MODEL

RAINFALL FOR YEAR 1969 ZERQA RIVER STREAMFLOW SIMULATION VALUES IN MILLIM

DAY	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	DAY
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3
4	0.000	0.000	.700	.065	0.000	0.000	.320	0.000	0.000	0.000	0.000	0.000	4
5	0.000	0.000	2.410	.570	0.000	0.000	.620	0.000	0.000	0.000	0.000	0.000	5
6	0.000	0.000	4.710	.590	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	6
7	0.000	0.000	9.240	.810	7.640	.290	0.000	0.000	0.000	0.000	0.000	0.000	7
8	0.000	0.000	2.860	.050	5.710	0.000	0.000	0.000	0.000	0.000	0.000	0.000	8
9	0.000	0.000	.200	4.240	0.000	1.380	.250	0.000	0.000	0.000	0.000	0.000	9
10	0.000	0.000	0.000	0.000	0.000	.500	0.000	0.000	0.000	0.000	0.000	0.000	10
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	11
12	0.000	0.000	.200	4.450	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	12
13	0.000	0.000	0.000	3.620	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	13
14	0.000	0.000	4.150	2.050	0.000	0.000	.400	0.000	0.000	0.000	0.000	0.000	14
15	0.000	0.000	3.690	.500	0.000	0.000	3.870	0.000	0.000	0.000	0.000	0.000	15
16	0.000	0.000	.300	0.000	0.000	0.000	2.410	0.000	0.000	0.000	0.000	0.000	16
17	0.000	0.000	.390	0.000	0.000	0.000	3.130	1.570	0.000	0.000	0.000	0.000	17
18	0.000	0.000	0.000	.519	0.000	2.950	0.000	0.000	0.000	0.000	0.000	0.000	18
19	0.000	0.000	0.000	.720	0.000	25.720	0.000	0.000	0.000	0.000	0.000	0.000	19
20	0.000	0.000	0.000	1.570	0.000	24.870	0.000	0.000	0.000	0.000	0.000	0.000	20
21	0.000	0.000	0.000	9.170	0.000	16.280	0.000	0.000	0.000	0.000	0.000	0.000	21
22	0.000	0.000	.430	3.230	0.000	15.630	0.000	.160	0.000	0.000	0.000	0.000	22
23	0.000	5.790	0.000	1.250	0.000	6.500	.280	.060	0.000	0.000	0.000	0.000	23
24	0.000	1.070	0.000	3.560	0.000	1.200	0.000	0.000	0.000	0.000	0.000	0.000	24
25	.030	3.420	5.140	2.520	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	25
26	.030	0.000	10.860	1.100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	26
27	0.000	0.000	.900	2.710	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	27
28	0.000	0.000	0.000	13.920	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	28
29	0.000	0.000	0.000	14.190	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	29
30	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	30
31	.460	0.000	0.000	0.000	0.000	1.040	0.000	0.000	0.000	0.000	0.000	0.000	31
TOTAL	.62	10.28	45.28	71.44	13.35	95.76	11.28	1.79	0.00	0.00	0.00	0.00	

TOTAL FOR WATER YEAR = 249.52 MILLIMETERS

77/11/02

JORDAN CONTINUOUS DAILY STREAMFLOW SIMULATION MODEL

OBSERVED RUNOFF FOR YEAR 1969

ZERQA RIVER STREAMFLOW SIMULATION

VALUES IN CUBIC METERS PER SECOND

DAY	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	DAY
1	.920	.960	1.000	1.380	7.950	1.360	3.150	1.950	1.360	1.120	.840	.800	1
2	.920	.960	1.000	1.380	5.530	1.360	3.050	1.950	1.240	1.120	.840	.850	2
3	.920	1.040	1.050	1.340	2.930	1.260	2.950	2.180	1.210	1.120	.880	.890	3
4	.920	.920	1.100	1.380	2.180	1.260	2.950	2.250	1.180	1.180	.880	.980	4
5	.920	.880	1.190	1.380	2.180	1.160	3.050	2.250	1.240	1.120	.720	.980	5
6	.920	.880	1.380	1.430	1.970	1.110	3.050	2.100	1.360	1.120	.800	.890	6
7	.920	.920	1.380	1.480	2.040	1.210	2.950	2.100	1.360	1.070	.720	.980	7
8	.920	.960	2.190	1.430	5.520	1.260	2.580	2.030	1.360	1.070	.800	1.070	8
9	.920	1.000	2.290	1.430	5.670	1.210	2.400	1.950	1.300	1.180	.760	1.100	9
10	.920	1.000	1.730	1.430	3.070	1.260	2.400	1.950	1.300	1.070	.800	1.120	10
11	.920	1.000	1.540	1.430	2.350	1.300	2.330	1.880	1.300	1.070	.720	1.070	11
12	.920	.880	1.480	1.430	2.350	1.260	2.330	1.880	1.360	.980	.720	1.070	12
13	.920	.960	1.430	1.600	2.270	1.210	2.250	1.880	1.240	1.070	.750	1.020	13
14	.920	.960	1.380	1.850	2.270	1.110	2.100	1.880	1.180	1.020	.750	.980	14
15	.920	1.000	1.980	1.850	2.100	1.060	2.100	1.800	1.180	.960	.760	.980	15
16	.920	1.000	1.760	1.730	2.180	1.000	2.180	1.730	1.300	.890	.890	1.020	16
17	.920	1.040	1.540	1.600	1.970	1.000	2.680	1.800	1.300	.890	.720	1.080	17
18	.920	.960	1.430	1.600	1.900	1.000	3.150	1.800	1.300	.980	.720	1.180	18
19	.920	.960	1.380	1.600	1.900	4.910	3.150	1.660	1.300	.960	.720	1.100	19
20	.920	1.000	1.380	1.600	1.900	60.100	2.680	1.590	1.240	.940	.760	1.120	20
21	.920	1.000	1.340	1.790	1.830	39.300	2.490	1.590	1.360	.890	.820	1.180	21
22	.920	1.000	1.340	2.970	1.750	87.500	2.250	1.530	1.240	.840	.890	1.120	22
23	.920	1.000	1.340	2.970	1.750	63.100	2.250	1.410	1.180	.840	.940	1.070	23
24	.920	1.500	1.340	2.330	1.610	19.100	2.180	1.410	1.300	.890	.890	1.100	24
25	.920	1.750	1.340	2.510	1.400	8.300	2.030	1.410	1.240	.890	.890	1.120	25
26	.920	2.230	1.660	2.790	1.480	5.530	2.030	1.470	1.180	.890	.800	1.070	26
27	.880	3.230	2.530	1.970	1.480	4.210	2.030	1.530	1.070	.890	.760	1.070	27
28	.840	1.600	1.790	3.910	1.550	3.680	2.030	1.530	1.070	.940	.660	1.070	28
29	.880	1.290	1.600	10.300	0.000	3.450	1.950	1.410	1.020	.940	.720	1.070	29
30	.960	1.140	1.480	9.220	0.000	3.450	1.950	1.410	1.120	.890	.750	1.070	30
31	1.000	0.000	1.430	4.910	0.000	2.950	1.950	1.410	0.000	.840	.760	0.000	31
TOTAL	28.480	35.020	46.800	76.020	73.080	326.970	74.520	54.720	37.390	30.690	24.380	31.380	

TOTAL FOR WATER YEAR = 839.290 CUBIC METERS PER SECOND

= 23.27 MILLIMETERS

THE FOLLOWING IS THE FIXED AND INITIAL PARAMETER VALUES

PARAMETER	BSMI	BGMR	MCEPT	SOKM	FRCK	SGMK	PGMK	SROK	PIMP	TRLOS
FIXED VALUE	20.000	33.000	4.000	3116.000	.300	.990	.999	.250	0.000	0.000

PARAMETER	FMAX	FMIN	ALFN	AMORD	BHORP	FSRD	REXP	BHORD	EPAR	DLOSS
INITIAL VALUE	420.000	30.000	.100	50.000	10.000	.100	1.000	90.000	.500	0.000
UPPER LIMIT	600.000	60.000	.400	100.000	50.000	.150	4.000	200.000	1.000	.800
LOWER LIMIT	300.000	10.000	.050	20.000	5.000	.100	1.000	60.000	.500	0.000
INCREMENT	10.000	2.000	.010	2.000	2.000	.010	.100	2.000	.050	.050

TRIAL 3 RUN 30

OPTIMIZATION CRITERIA (THIS RUN) 10.745502

OPTIMIZATION CRITERIA (BEST PRIOR RUN) 10.511349

THE FOLLOWING IS THE FIXED AND INITIAL PARAMETER VALUES

PARAMETER	OSMI	BGWR	WCEPT	SQKM	FRCK	SGWK	PGWK	SROK	PIMP	TRLOS
FIXED VALUE	20.000	33.000	4.000	3116.000	.300	.990	.999	.250	0.000	0.000

PARAMETER	FMAX	FMIN	ALFN	AHORD	BHORP	FSRO	REXP	BHORD	EPAR	DLOSS
INITIAL VALUE	420.000	30.000	.100	50.000	10.000	.100	1.000	90.000	.500	0.000
UPPER LIMIT	600.000	60.000	.400	110.000	50.000	.150	4.000	200.000	1.000	.800
LOWER LIMIT	300.000	10.000	.050	20.000	5.000	.100	1.000	60.000	.500	0.000
INCREMENT	10.000	2.000	.010	2.000	2.000	.010	.100	2.000	.050	.050

THE FOLLOWING IS THE OPTIMIZATION RESULT THIS RUN

PARAMETER	FMAX	FMIN	ALFN	AHORD	BHORP	FSRO	REXP	BHORD	EPAR	DLOSS
PRESENT VALUE	480.000	42.000	.070	62.000	6.000	.130	1.500	100.000	.750	.250

STATISTICS	EXPA	EXPB	ERROR	SSERR	SSLOG	ABSV	OBFN	CCOF	SLOPE	YINT
	1.6000	0.0000	-5.6398	5.8174	7.2067	10.7455	10.7455	.9296	.6241	.0240

77/11/01

JORDAN CONTINUOUS DAILY STREAMFLOW SIMULATION MODEL

DAILY MOISTURE ALLOCATION (VALUES IN MILLIMETERS)

YEAR	MO	DAY	RAIN	PET	AET	PSRO	SURVCL	SURES	SURO	IPVOL	IFRES	IFRO	INFL	DRAIN	RECHAR	DLOSS	PGWR	GWRK	GWRO	AHOR	BHOR
1969	4	1	0.00	3.25	2.93	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	.17	.3426	.0349	35.1567	.9973	.0942	11.64	71.39
1969	4	2	0.00	2.60	2.31	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	.11	.0270	.0221	35.0913	.9974	.0924	9.45	71.42
1969	4	3	0.00	4.55	3.90	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	.04	.0096	.0074	35.0112	.9974	.0901	5.49	71.38
1969	4	4	.32	1.95	1.69	0.0000	.0003	0.0000	.0000	0.0000	0.0000	0.0000	.01	.02	.0051	.0042	34.9275	.9975	.0878	4.13	71.36
1969	4	5	.62	2.60	2.25	0.0000	.0000	0.0000	.0000	0.0000	0.0000	0.0000	.05	.01	.0019	.0015	34.8440	.9976	.0854	2.52	71.33
1969	4	6	0.00	2.60	2.09	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	.06	.0001	.0001	34.7616	.9976	.0831	.49	71.27
1969	4	7	0.00	3.25	.76	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.0000	0.0000	34.6832	.9977	.0808	0.00	71.01
1969	4	8	0.00	3.25	.31	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.0000	0.0000	34.6116	.9977	.0786	0.00	70.70
1969	4	9	.05	2.60	.29	0.0000	.0066	0.0000	.0000	0.0000	0.0000	0.0000	.00	0.00	0.0000	0.0000	34.5251	.9978	.0765	.00	70.47
1969	4	10	0.00	3.90	.36	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.0000	0.0000	34.4560	.9978	.0744	0.00	70.11
1969	4	11	0.00	3.25	.29	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.0000	0.0000	34.3784	.9979	.0723	0.00	69.82
1969	4	12	0.00	3.90	.34	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.0000	0.0000	34.3081	.9980	.0704	0.00	69.48
1969	4	13	0.00	3.25	.20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.0000	0.0000	34.2396	.9980	.0684	0.00	69.26
1969	4	14	.43	5.20	.79	0.0000	.0000	0.0000	.0000	0.0000	0.0000	0.0000	.02	0.00	0.0000	0.0000	34.1730	.9981	.0666	.02	68.79
1969	4	15	3.87	1.30	1.32	0.0000	.0056	.0040	.0004	0.0000	0.0000	0.0000	2.56	.01	.0019	.0016	34.1162	.9981	.0648	2.58	66.79
1969	4	16	2.41	3.90	3.46	0.0000	.0005	.0016	.0036	0.0000	0.0000	0.0000	.73	.00	.0007	.0006	34.0470	.9982	.0631	1.57	68.76
1969	4	17	3.13	1.30	1.30	0.0000	.0331	.0030	.0016	0.0000	0.0000	0.0000	1.83	.02	.0034	.0027	33.9897	.9982	.0615	3.38	68.76
1969	4	18	0.09	1.95	1.59	0.0000	0.0000	.0008	.0023	0.0000	0.0000	0.0000	0.09	.00	.0010	.0008	33.9364	.9982	.0598	1.82	68.73
1969	4	19	0.00	3.90	1.99	0.0000	0.0000	.0002	.0008	0.0000	0.0000	0.0000	0.00	0.00	0.0000	0.0000	33.8727	.9983	.0582	0.00	68.56
1969	4	20	0.00	5.20	.42	0.0000	0.0000	0.0000	.0001	0.0000	0.0000	0.0000	0.00	0.00	0.0000	0.0000	33.8161	.9983	.0566	0.00	68.14
1969	4	21	0.00	5.20	.41	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.0000	0.0000	33.7610	.9984	.0551	0.00	67.73
1969	4	22	0.00	7.15	.55	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.0000	0.0000	33.7074	.9984	.0536	0.00	67.17
1969	4	23	.20	3.90	.54	0.0000	.0000	0.0000	.0000	0.0000	0.0000	0.0000	.01	0.00	0.0000	0.0000	33.6553	.9985	.0521	.61	66.96
1969	4	24	0.00	3.90	.30	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.0000	0.0000	33.6046	.9985	.0507	0.00	66.61
1969	4	25	0.00	4.55	.33	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.0000	0.0000	33.5553	.9985	.0493	0.00	66.28
1969	4	26	0.00	3.25	.23	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.0000	0.0000	33.5073	.9986	.0480	0.00	66.35
1969	4	27	0.00	3.90	.27	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.0000	0.0000	33.4606	.9986	.0467	0.00	65.78
1969	4	28	0.00	3.90	.27	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.0000	0.0000	33.4151	.9986	.0454	0.00	65.51
1969	4	29	0.00	5.20	.35	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.0000	0.0000	33.3749	.9987	.0442	0.00	65.16
1969	4	30	0.00	6.50	.43	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.0000	0.0000	33.3279	.9987	.0430	0.00	64.73

THE FOLLOWING ARE MONTHLY TOTALS IN MILLIMETERS

RAINFALL	=	11.08
MOISTURE IN DEPRESSION STORAGE	=	7.17
POTENTIAL EVAPORATION	=	111.15
ESTIMATED ACTUAL EVAPORATION	=	32.42
EVAPORATION FROM DEPRESSION STORAGE	=	5.86
EVAPORATION FROM A HORIZON STORAGE	=	19.75
EVAPORATION FROM B HORIZON STORAGE	=	6.81
GROUNDWATER RECHARGE	=	.09

RUNOFF FROM IMPERVIOUS AREAS	=	0.00
SURFACE RUNOFF	=	.01
INTERFLOW THRU A HORIZON	=	0.00
BASE FLOW	=	1.97
LOSSES THRU SEEPS AND SPRINGS	=	.08
TOTALL SIMULATED RUNOFF	=	1.96
TOTAL OBSERVED RUNOFF	=	2.07

THE FOLLOWING ARE ANNUAL TOTALS IN MILLIMETERS

RAINFALL	=	249.52
MOISTURE IN DEPRESSION STORAGE	=	79.92
POTENTIAL EVAPORATION	=	1853.90
ESTIMATED ACTUAL EVAPORATION	=	210.85
EVAPORATION FROM DEPRESSION STORAGE	=	47.93
EVAPORATION FROM A HORIZON STORAGE	=	123.28
EVAPORATION FROM B HORIZON STORAGE	=	39.64
GROUNDWATER RECHARGE	=	0.37

RUNOFF FROM IMPERVIOUS AREAS	=	0.00
SURFACE RUNOFF	=	8.41
INTERFLOW THRU A HORIZON	=	0.00
BASE FLOW	=	12.81
LOSSES THRU SEEPS AND SPRINGS	=	6.85
TOTALL SIMULATED RUNOFF	=	21.21
TOTAL OBSERVED RUNOFF	=	23.27

THE FOLLOWING IS THE FIXED AND INITIAL PARAMETER VALUES

PARAMETER	BSMI	BGWR	WCEPT	SOKM	FRCK	SGWK	PGWK	SROK	PIMP	TRLOS
FIXED VALUE	20.000	33.000	4.000	3116.000	.300	.990	.999	.250	0.000	0.000

PARAMETER	FMAX	FMIN	ALFN	AHORD	BHORP	FSRO	REXP	BHORD	EPAR	DLOSS
INITIAL VALUE	420.000	30.000	.100	50.000	10.000	.100	1.000	90.000	.500	0.000
UPPER LIMIT	600.000	60.000	.400	100.000	50.000	.150	4.000	200.000	1.000	.800
LOWER LIMIT	300.000	10.000	.050	20.000	5.000	.100	1.000	60.000	.500	0.000
INCREMENT	5.000	1.000	.005	1.000	1.000	.005	.050	1.000	.025	.025

THE FOLLOWING IS THE FINAL OPTIMIZATION RESULTS

PARAMETER	FMAX	FMIN	ALFN	AHORD	BHORP	FSRO	REXP	BHORD	EPAR	DLOSS
BEST VALUE	595.000	33.000	.060	60.000	10.000	.145	2.000	105.000	.725	.450

STATISTICS	EXPA	EXPB	ERROR	SSERR	SSLOG	ABSV	OBFN	CCOF	SLOPE	YINT
	1.0000	0.0000	2.0576	2.1461	6.3310	6.5637	6.5637	.9144	1.0766	-.0045

SIMULATED RUNOFF FOR ZERCA RIVER STREAMFLOW SIMULATION (OPTIMIZATION)

WATER YEAR 1969

DAY	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	DAY
1	1.190	1.154	1.120	1.088	2.615	1.099	3.398	1.509	1.164	1.129	1.095	1.062	1
2	1.189	1.153	1.119	1.087	1.473	1.098	3.332	1.468	1.163	1.128	1.094	1.060	2
3	1.188	1.151	1.118	1.086	1.190	1.097	3.249	1.429	1.162	1.127	1.093	1.059	3
4	1.187	1.150	1.116	1.085	1.120	1.096	3.165	1.390	1.160	1.126	1.092	1.058	4
5	1.185	1.149	1.121	1.084	1.104	1.095	3.081	1.353	1.159	1.125	1.091	1.057	5
6	1.184	1.148	1.243	1.083	1.099	1.093	2.996	1.316	1.158	1.124	1.089	1.056	6
7	1.183	1.147	1.823	1.082	1.459	1.092	2.915	1.281	1.157	1.123	1.088	1.055	7
8	1.182	1.146	2.309	1.081	2.995	1.091	2.835	1.246	1.156	1.122	1.087	1.054	8
9	1.181	1.145	1.449	1.138	2.860	1.090	2.757	1.213	1.155	1.120	1.086	1.053	9
10	1.179	1.143	1.195	1.336	1.548	1.089	2.682	1.190	1.153	1.119	1.085	1.052	10
11	1.178	1.142	1.131	1.142	1.226	1.088	2.609	1.189	1.152	1.118	1.084	1.051	11
12	1.177	1.141	1.114	1.126	1.139	1.087	2.538	1.187	1.151	1.117	1.083	1.050	12
13	1.176	1.140	1.107	1.281	1.119	1.086	2.469	1.186	1.150	1.116	1.082	1.049	13
14	1.175	1.139	1.155	1.367	1.113	1.085	2.401	1.185	1.149	1.115	1.081	1.048	14
15	1.174	1.138	1.357	1.263	1.113	1.084	2.367	1.184	1.148	1.114	1.080	1.047	15
16	1.172	1.137	1.332	1.120	1.112	1.083	2.406	1.183	1.147	1.113	1.079	1.046	16
17	1.171	1.135	1.166	1.083	1.112	1.081	2.275	1.182	1.145	1.112	1.078	1.045	17
18	1.170	1.134	1.117	1.073	1.111	1.086	2.239	1.180	1.144	1.110	1.076	1.044	18
19	1.169	1.133	1.105	1.069	1.110	3.919	2.119	1.179	1.143	1.109	1.075	1.043	19
20	1.168	1.132	1.100	1.082	1.109	22.762	2.047	1.178	1.142	1.108	1.074	1.042	20
21	1.167	1.131	1.099	1.623	1.108	53.699	1.986	1.177	1.141	1.107	1.073	1.040	21
22	1.165	1.130	1.098	3.381	1.107	61.269	1.932	1.176	1.140	1.106	1.072	1.039	22
23	1.164	1.243	1.097	2.078	1.106	63.148	1.880	1.174	1.139	1.105	1.071	1.038	23
24	1.163	1.632	1.096	1.416	1.104	26.468	1.829	1.173	1.137	1.104	1.070	1.037	24
25	1.162	1.267	1.138	1.625	1.103	8.729	1.779	1.172	1.136	1.103	1.069	1.036	25
26	1.161	1.206	1.766	1.531	1.102	4.516	1.731	1.171	1.135	1.102	1.068	1.035	26
27	1.160	1.145	3.265	1.255	1.101	3.629	1.684	1.170	1.134	1.100	1.067	1.034	27
28	1.158	1.128	1.636	4.039	1.100	3.497	1.639	1.169	1.133	1.099	1.066	1.033	28
29	1.157	1.122	1.227	17.854	0.000	3.486	1.594	1.167	1.132	1.098	1.065	1.032	29
30	1.156	1.121	1.124	25.511	0.000	3.485	1.551	1.166	1.131	1.097	1.064	1.031	30
31	1.155	0.000	1.098	7.192	0.000	3.451	0.000	1.165	0.000	1.096	1.063	0.000	31
TOTAL	36.346	34.985	40.934	98.262	37.552	261.677	71.485	38.107	34.414	34.493	33.439	31.388	

TOTAL FOR WATER YEAR = 765.083 CUBIC METERS PER SECOND

= 21.21 MILLIMETERS

THE FOLLOWING ARE ANNUAL TOTALS IN MILLIMETERS

RAINFALL	= 249.52
MOISTURE IN DEPRESSION STORAGE	= 79.92
POTENTIAL EVAPORATION	= 1853.98
ESTIMATED ACTUAL EVAPORATION	= 197.57
EVAPORATION FROM DEPRESSION STORAGE	= 47.93
EVAPORATION FROM A HORIZON STORAGE	= 139.98
EVAPORATION FROM B HORIZON STORAGE	= 9.66
GROUNDWATER RECHARGE	= 9.34

RUNOFF FROM IMPERVIOUS AREAS	= 0.00
SURFACE RUNOFF	= 9.20
INTERFLOW THRU A HORIZON	= 0.06
BASE FLOW	= 13.56
LOSSES THRU SEEPS AND SPRINGS	= 3.11
TOTALL SIMULATED RUNOFF	= 22.76
TOTAL OBSERVED RUNOFF	= 23.27

THE FOLLOWING IS THE FIXED AND INITIAL PARAMETER VALUES

PARAMETER	BSMI	BGWR	NCEPT	SQKM	FRCK	SGWK	PGWK	SROK	PIMP	TRLOS
FIXED VALUE	20.000	33.000	4.000	3116.000	.300	.990	.999	.250	0.000	0.000

PARAMETER	FMAX	FMIN	ALFN	AHORD	BHORP	FSRO	REXP	BHORD	EPAR	DLOSS
INITIAL VALUE	420.000	30.000	.100	50.000	10.000	.100	1.000	90.000	.500	0.000
UPPER LIMIT	600.000	60.000	.400	160.000	50.000	.150	4.000	200.000	1.000	.800
LOWER LIMIT	300.000	10.000	.050	20.000	5.000	.100	1.000	60.000	.500	0.000
INCREMENT	5.000	1.000	.005	1.000	1.000	.005	.050	1.000	.025	.025

THE FOLLOWING IS THE FINAL OPTIMIZATION RESULTS

PARAMETER	FMAX	FMIN	ALFN	AHORD	BHORP	FSRO	REXP	BHORD	EPAR	DLOSS
BEST VALUE	450.000	55.000	.070	78.000	6.000	.140	1.200	134.000	.800	.250

STATISTICS	EXPA	EXPB	ERROR	SSERR	SSLOG	ABSV	OBFN	CCOF	SLOPE	YINT
	0.0000	0.0000	.5100	2.5335	5.7517	7.2112	5.7517	.8952	1.0050	-.0003

SIMULATED RUNOFF FOR ZERQA RIVER STREAMFLOW SIMULATION (OPTIMIZATION) WATER YEAR 1969

DAY	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	DAY
1	1.190	1.154	1.120	1.094	3.053	1.134	4.067	1.857	1.173	1.138	1.103	1.070	1
2	1.189	1.153	1.119	1.090	1.594	1.133	4.023	1.807	1.172	1.137	1.102	1.068	2
3	1.188	1.151	1.118	1.088	1.232	1.132	3.951	1.758	1.170	1.136	1.101	1.067	3
4	1.187	1.150	1.117	1.087	1.143	1.131	3.872	1.710	1.169	1.135	1.100	1.066	4
5	1.185	1.149	1.122	1.086	1.123	1.130	3.787	1.664	1.168	1.133	1.099	1.065	5
6	1.184	1.148	1.280	1.085	1.118	1.129	3.695	1.619	1.167	1.132	1.098	1.064	6
7	1.183	1.147	2.053	1.084	1.771	1.127	3.599	1.575	1.166	1.131	1.097	1.063	7
8	1.182	1.146	2.731	1.083	4.633	1.126	3.501	1.532	1.165	1.130	1.096	1.062	8
9	1.181	1.145	1.569	1.156	4.254	1.126	3.405	1.491	1.163	1.129	1.094	1.061	9
10	1.179	1.143	1.226	1.423	1.915	1.124	3.311	1.451	1.162	1.128	1.093	1.060	10
11	1.178	1.142	1.139	1.165	1.332	1.123	3.221	1.412	1.161	1.127	1.092	1.059	11
12	1.177	1.141	1.117	1.144	1.188	1.122	3.132	1.373	1.160	1.126	1.091	1.058	12
13	1.176	1.140	1.109	1.351	1.154	1.121	3.047	1.336	1.159	1.124	1.090	1.057	13
14	1.175	1.139	1.173	1.472	1.146	1.120	2.963	1.300	1.158	1.123	1.089	1.056	14
15	1.174	1.138	1.461	1.334	1.144	1.118	2.921	1.265	1.156	1.122	1.088	1.055	15
16	1.172	1.137	1.428	1.140	1.145	1.117	2.979	1.231	1.155	1.121	1.087	1.054	16
17	1.171	1.135	1.186	1.090	1.145	1.116	2.809	1.199	1.154	1.120	1.086	1.053	17
18	1.170	1.134	1.124	1.077	1.145	1.122	2.767	1.189	1.153	1.119	1.085	1.052	18
19	1.169	1.133	1.108	1.072	1.144	4.754	2.612	1.188	1.152	1.118	1.084	1.050	19
20	1.168	1.132	1.102	1.089	1.144	29.015	2.521	1.187	1.151	1.117	1.082	1.049	20
21	1.167	1.131	1.101	1.812	1.143	65.226	2.446	1.186	1.149	1.115	1.081	1.048	21
22	1.165	1.130	1.150	4.269	1.142	60.565	2.379	1.184	1.148	1.114	1.080	1.047	22
23	1.164	1.274	1.099	2.472	1.141	54.866	2.315	1.183	1.147	1.113	1.079	1.046	23
24	1.163	1.798	1.098	1.552	1.140	22.267	2.252	1.182	1.146	1.112	1.078	1.045	24
25	1.162	1.314	1.152	1.854	1.139	7.945	2.193	1.181	1.145	1.111	1.077	1.044	25
26	1.161	1.237	1.971	1.728	1.138	4.626	2.131	1.180	1.144	1.110	1.076	1.043	26
27	1.160	1.152	4.015	1.336	1.137	4.003	2.073	1.179	1.143	1.109	1.075	1.042	27
28	1.158	1.130	1.825	5.228	1.135	3.981	2.017	1.177	1.141	1.108	1.074	1.041	28
29	1.157	1.122	1.276	24.239	0.000	4.036	1.962	1.176	1.140	1.107	1.073	1.040	29
30	1.156	1.121	1.138	32.325	0.000	4.085	1.909	1.175	1.139	1.105	1.072	1.039	30
31	1.155	0.000	1.103	8.904	0.000	4.090	0.000	1.174	0.000	1.104	1.071	0.000	31
TOTAL	36.346	35.268	43.280	108.931	42.637	289.709	87.855	42.121	34.675	34.754	33.693	31.626	

TOTAL FOR WATER YEAR = 820.896 CUBIC METERS PER SECOND

= 22.76 MILLIMETERS

77/11/02

JORDAN CONTINUOUS DAILY STREAMFLOW SIMULATION MODEL

ZERQA RIVER STREAMFLOW SIMULATION

FOLLOWING ARE PARAMETERS AND CONSTANTS FOR YEAR(S) 1969-1973

BSMI	BGWR	FMAX	FMIN	AHORD	BHORP	BHORD	REXP	WCEPT	SQKM
20.00	33.00	595.00	33.00	65.00	10.00	105.00	2.00	4.00	3116.00
EPAR	FSRO	SROK	FROK	SGWK	PGWK	ALFN	DLOSS	PIMP	TRLOS
.725	.145	.250	.300	.990	.999	.060	.450	0.000	0.000

SIMULATED RUNOFF FOR ZERQA RIVER STREAMFLOW SIMULATION

WATER YEAR 1969

DAY	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	DAY
1	1.190	1.154	1.120	1.088	2.615	1.099	3.398	1.589	1.164	1.129	1.095	1.062	1
2	1.189	1.153	1.119	1.087	1.473	1.098	3.332	1.460	1.163	1.128	1.094	1.060	2
3	1.188	1.151	1.118	1.086	1.190	1.097	3.249	1.429	1.162	1.127	1.093	1.059	3
4	1.187	1.150	1.116	1.085	1.120	1.096	3.165	1.390	1.160	1.126	1.092	1.058	4
5	1.185	1.149	1.121	1.084	1.104	1.095	3.381	1.353	1.159	1.125	1.091	1.057	5
6	1.184	1.148	1.243	1.083	1.099	1.093	2.996	1.316	1.158	1.124	1.089	1.056	6
7	1.183	1.147	1.823	1.082	1.459	1.092	2.915	1.281	1.157	1.123	1.088	1.055	7
8	1.182	1.146	2.309	1.081	2.995	1.091	2.835	1.246	1.156	1.122	1.087	1.054	8
9	1.181	1.145	1.449	1.138	2.060	1.090	2.757	1.213	1.155	1.120	1.086	1.053	9
10	1.179	1.143	1.195	1.336	1.548	1.089	2.682	1.190	1.153	1.119	1.085	1.052	10
11	1.178	1.142	1.131	1.142	1.220	1.088	2.609	1.189	1.152	1.118	1.084	1.051	11
12	1.177	1.141	1.114	1.126	1.139	1.087	2.538	1.187	1.151	1.117	1.083	1.050	12
13	1.176	1.140	1.107	1.281	1.119	1.086	2.469	1.186	1.150	1.116	1.082	1.049	13
14	1.175	1.139	1.155	1.367	1.113	1.085	2.481	1.185	1.149	1.115	1.081	1.048	14
15	1.174	1.138	1.357	1.263	1.113	1.084	2.367	1.184	1.148	1.114	1.080	1.047	15
16	1.172	1.137	1.332	1.120	1.112	1.083	2.406	1.183	1.147	1.113	1.079	1.046	16
17	1.171	1.135	1.160	1.063	1.112	1.081	2.275	1.182	1.145	1.112	1.078	1.045	17
18	1.170	1.134	1.117	1.073	1.111	1.086	2.239	1.180	1.144	1.110	1.076	1.044	18
19	1.169	1.133	1.105	1.069	1.118	3.919	2.119	1.179	1.143	1.109	1.075	1.043	19
20	1.168	1.132	1.100	1.082	1.109	22.762	2.047	1.178	1.142	1.108	1.074	1.042	20
21	1.167	1.131	1.099	1.623	1.108	53.699	1.986	1.177	1.141	1.107	1.073	1.040	21
22	1.165	1.130	1.098	3.381	1.107	61.269	1.932	1.176	1.140	1.106	1.072	1.039	22
23	1.164	1.243	1.097	2.078	1.106	63.148	1.880	1.174	1.139	1.105	1.071	1.038	23
24	1.163	1.532	1.096	1.416	1.104	26.468	1.829	1.173	1.137	1.104	1.070	1.037	24
25	1.162	1.267	1.138	1.625	1.103	8.729	1.779	1.172	1.136	1.103	1.069	1.036	25
26	1.161	1.208	1.766	1.531	1.102	4.516	1.731	1.171	1.135	1.102	1.068	1.035	26
27	1.160	1.145	3.265	1.255	1.101	3.629	1.684	1.170	1.134	1.100	1.067	1.034	27
28	1.158	1.128	1.636	4.039	1.100	3.497	1.639	1.169	1.133	1.099	1.066	1.033	28
29	1.157	1.122	1.227	17.854	0.000	3.486	1.594	1.167	1.132	1.098	1.065	1.032	29
30	1.156	1.121	1.124	25.511	0.000	3.485	1.551	1.166	1.131	1.097	1.064	1.031	30
31	1.155	0.000	1.098	7.192	0.000	3.451	0.000	1.165	0.000	1.096	1.063	0.000	31
TOTAL	36.346	34.985	40.934	90.262	37.552	201.677	71.485	30.107	34.414	34.493	33.439	31.380	

TOTAL FOR WATER YEAR = 765.083 CUBIC METERS PER SECOND

= 21.21 MILLIMETERS

77/11/02

JORDAN CONTINUOUS DAILY STREAMFLOW SIMULATION MODEL

THE FOLLOWING ARE ANNUAL TOTALS IN MILLIMETERS

RAINFALL	=	249.52
MOISTURE IN DEPRESSION STORAGE	=	79.92
POTENTIAL EVAPORATION	=	1853.90
ESTIMATED ACTUAL EVAPORATION	=	210.85
EVAPORATION FROM DEPRESSION STORAGE	=	47.93
EVAPORATION FROM A HORIZON STORAGE	=	123.28
EVAPORATION FROM B HORIZON STORAGE	=	39.64
GROUNDWATER RECHARGE	=	8.37

RUNOFF FROM IMPERVIOUS AREAS	=	0.00
SURFACE RUNOFF	=	0.41
INTERFLOW THRU A HORIZON	=	0.00
BASE FLOW	=	12.81
LOSSES THRU SEEPS AND SPRINGS	=	6.85
TOTALL SIMULATED RUNOFF	=	21.21
TOTAL OBSERVED RUNOFF	=	23.27

77/11/02

JORDAN CONTINUOUS DAILY STREAMFLOW SIMULATION MODEL

RAINFALL FOR YEAR 1970

ZERQA RIVER STREAMFLOW SIMULATION

VALUES IN MILLIM

DAY	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	DAY
1	0.000	1.560	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1
2	0.000	3.400	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3
4	0.000	0.000	.280	.720	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	4
5	0.000	0.000	0.000	.170	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	5
6	.370	0.000	0.000	0.000	6.190	0.000	0.000	0.000	0.000	0.000	0.000	0.000	6
7	.010	.470	0.000	0.000	.390	0.000	0.000	0.000	0.000	0.000	0.000	0.000	7
8	.360	.840	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	8
9	5.110	0.000	0.000	.520	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	9
10	0.000	0.000	0.000	.830	0.000	4.780	0.000	0.000	0.000	0.000	0.000	0.000	10
11	0.000	0.000	0.000	0.000	0.000	12.980	0.000	0.000	0.000	0.000	0.000	0.000	11
12	0.000	0.000	0.000	0.000	0.000	9.180	0.000	0.000	0.000	0.000	0.000	0.000	12
13	0.000	0.000	.150	0.000	0.000	.520	0.000	0.000	0.000	0.000	0.000	0.000	13
14	0.000	0.000	0.000	.390	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	14
15	0.000	0.000	0.000	1.490	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	15
16	0.000	0.000	1.530	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	16
17	0.000	0.000	0.000	0.000	.140	0.000	0.000	0.000	0.000	0.000	0.000	0.000	17
18	0.000	0.000	.680	0.000	2.260	0.000	0.000	0.000	0.000	0.000	0.000	0.000	18
19	3.200	0.000	0.000	.260	0.000	.400	3.160	0.000	0.000	0.000	0.000	0.000	19
20	1.540	0.000	0.000	0.000	0.000	1.340	4.380	0.000	0.000	0.000	0.000	0.000	20
21	1.520	0.000	0.000	7.590	1.640	.070	1.920	0.000	0.000	0.000	0.000	0.000	21
22	0.000	0.000	.020	11.890	7.950	4.870	0.000	0.000	0.000	0.000	0.000	0.000	22
23	.610	0.000	2.090	8.830	2.220	28.470	0.000	0.000	0.000	0.000	0.000	0.000	23
24	0.000	0.000	0.000	1.880	.040	2.240	0.000	0.000	0.000	0.000	0.000	0.000	24
25	0.000	0.000	0.000	6.240	0.000	.030	0.000	0.000	0.000	0.000	0.000	0.000	25
26	0.000	0.000	1.880	4.640	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	26
27	0.000	0.000	0.000	.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	27
28	0.000	.260	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	28
29	0.000	3.910	0.000	0.000	0.000	0.000	.020	0.000	0.000	0.000	0.000	0.000	29
30	0.000	0.000	.680	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	30
31	0.000	0.000	.710	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	31
TOTAL	12.72	10.44	8.02	44.66	20.83	64.88	9.48	0.00	0.00	0.00	0.00	0.00	

TOTAL FOR WATER YEAR = 171.03 MILLIMETERS

77/11/02

JORDAN CONTINUOUS DAILY STREAMFLOW SIMULATION MODEL

OBSERVED RUNOFF FOR YEAR 1970

ZERQA RIVER STREAMFLOW SIMULATION

VALUES IN CUBIC METERS PER SECOND

DAY	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	DAY
1	1.020	1.120	1.180	1.530	1.750	1.440	1.440	1.320	1.260	.880	1.440	1.620	1
2	1.020	1.410	1.180	1.410	1.680	1.440	1.380	1.320	1.260	.840	1.440	1.560	2
3	1.120	1.470	1.180	1.410	1.620	1.380	1.380	1.200	1.380	.840	1.250	1.560	3
4	1.070	1.470	1.180	1.410	1.620	1.260	1.500	1.260	1.380	.880	1.320	1.620	4
5	1.070	1.410	1.240	1.360	1.620	1.200	1.500	1.320	1.500	.800	1.440	1.620	5
6	1.120	1.300	1.240	1.410	2.050	1.100	1.440	1.380	1.500	.800	1.550	1.560	6
7	1.300	1.360	1.180	1.360	1.750	1.050	1.320	1.260	1.380	.800	1.620	1.500	7
8	1.240	1.410	1.120	1.240	1.620	1.080	1.200	1.260	1.380	.800	1.620	1.500	8
9	1.240	1.360	1.240	1.240	1.620	1.100	1.200	1.150	1.260	.800	1.620	1.500	9
10	1.410	1.300	1.300	11.300	1.560	1.380	1.150	1.100	1.100	.840	1.620	1.500	10
11	1.300	1.300	1.300	8.730	1.500	4.220	1.100	1.150	1.150	.800	1.620	1.560	11
12	1.180	1.300	1.300	1.390	1.500	12.200	1.050	1.150	1.150	.710	1.560	1.680	12
13	1.120	1.300	1.240	1.500	1.440	2.360	1.150	1.050	1.150	.710	1.500	1.620	13
14	1.070	1.240	1.240	1.380	1.380	1.880	1.200	1.100	1.150	.710	1.620	1.560	14
15	1.180	1.300	1.180	1.440	1.380	1.750	1.200	1.050	1.440	.670	1.620	1.560	15
16	1.180	1.240	1.180	1.440	1.380	1.500	1.260	1.100	1.200	.800	1.620	1.560	16
17	1.120	1.180	1.180	1.300	1.440	1.260	1.380	1.200	1.200	.880	1.440	1.620	17
18	1.180	1.180	1.180	1.380	1.500	1.260	1.440	1.150	1.150	.970	1.440	1.680	18
19	1.180	1.180	1.300	1.380	1.380	1.380	1.750	1.200	1.070	.970	1.620	1.680	19
20	1.240	1.180	1.300	1.380	1.380	1.320	1.880	1.200	1.000	.970	1.560	1.880	20
21	1.360	1.180	1.180	1.560	1.500	1.260	1.820	1.100	.920	1.010	1.560	1.820	21
22	1.360	1.180	1.180	2.850	1.560	2.330	1.750	1.050	.970	1.100	1.500	1.880	22
23	1.360	1.180	1.240	2.940	1.960	22.800	1.820	1.100	.920	1.150	1.500	1.750	23
24	1.360	1.120	1.360	2.130	2.370	8.230	1.620	1.150	.970	1.260	1.560	1.880	24
25	1.300	1.180	1.360	2.070	1.880	3.000	1.500	1.260	.920	1.320	1.500	1.880	25
26	1.180	1.180	1.300	2.230	1.750	2.360	1.380	1.260	.920	1.380	1.500	1.820	26
27	1.120	1.180	1.410	2.450	1.620	2.020	1.380	1.380	.970	1.200	1.500	1.820	27
28	1.070	1.180	1.410	2.180	1.560	1.880	1.440	1.320	.920	1.010	1.620	1.750	28
29	1.120	1.240	1.410	1.950	0.000	1.880	1.380	1.260	.840	1.320	1.620	1.750	29
30	1.070	1.240	1.470	1.880	0.000	1.680	1.380	1.200	.880	1.500	1.620	1.880	30
31	1.180	0.000	1.530	1.820	0.000	1.500	0.000	1.260	0.000	1.440	1.620	0.000	31
TOTAL	36.840	37.870	39.290	69.130	45.370	90.500	42.390	37.260	34.290	30.160	47.640	50.170	

TOTAL FOR WATER YEAR = 560.910 CUBIC METERS PER SECOND

= 15.55 MILLIMETERS

SIMULATED RUNOFF FOR ZERQA RIVER STREAMFLOW SIMULATION WATER YEAR 1970

DAY	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	DAY
1	1.030	.999	1.000	.858	.946	.936	.946	.919	.891	.864	.838	.812	1
2	1.029	1.030	.976	.939	.947	.935	.945	.918	.890	.863	.837	.811	2
3	1.028	1.141	.967	.938	.947	.934	.945	.917	.889	.862	.836	.811	3
4	1.027	1.032	.966	.937	.948	.933	.944	.916	.888	.862	.835	.810	4
5	1.026	1.004	.965	.936	1.242	.932	.943	.915	.887	.861	.834	.809	5
6	1.025	.994	.964	.935	2.247	.931	.942	.914	.886	.860	.834	.808	6
7	1.024	.993	.964	.934	1.275	.931	.941	.913	.885	.859	.833	.807	7
8	1.023	.992	.963	.933	1.032	.930	.940	.912	.884	.858	.832	.807	8
9	1.064	.991	.962	.932	.971	.968	.939	.911	.883	.857	.831	.806	9
10	1.209	.990	.961	.931	.956	1.702	.938	.910	.883	.856	.830	.805	10
11	1.067	.989	.960	.930	.950	4.293	.937	.909	.882	.856	.829	.804	11
12	1.031	.988	.959	.929	.950	4.547	.936	.909	.881	.855	.829	.803	12
13	1.021	.987	.958	.929	.949	1.838	.935	.908	.880	.854	.828	.803	13
14	1.017	.986	.957	.928	.948	1.161	.934	.907	.879	.853	.827	.802	14
15	1.016	.985	.956	.930	.947	.992	.933	.906	.878	.852	.826	.801	15
16	1.015	.984	.955	.941	.946	.950	.932	.905	.877	.851	.825	.800	16
17	1.014	.983	.954	.929	.945	.938	.931	.904	.876	.850	.825	.799	17
18	1.013	.982	.955	.924	.957	.934	.946	.903	.876	.850	.824	.799	18
19	1.019	.981	.961	.923	1.000	.933	1.024	.902	.875	.849	.823	.798	19
20	1.046	.980	.951	.922	.957	.932	1.066	.901	.874	.848	.822	.797	20
21	1.034	.979	.950	1.136	.946	.968	.966	.900	.873	.847	.821	.796	21
22	1.027	.978	.949	2.790	1.189	4.714	.936	.899	.872	.846	.820	.795	22
23	1.012	.977	.957	6.034	2.060	16.992	.926	.899	.871	.845	.820	.795	23
24	1.007	.976	.988	5.641	1.359	5.046	.925	.898	.870	.845	.819	.794	24
25	1.006	.975	.956	3.039	1.044	1.974	.924	.897	.869	.844	.818	.793	25
26	1.005	.974	.947	4.650	.965	1.207	.923	.896	.869	.843	.817	.792	26
27	1.004	.973	.951	3.333	.945	1.015	.922	.895	.868	.842	.816	.791	27
28	1.003	.972	.943	1.539	.937	.966	.921	.894	.867	.841	.815	.791	28
29	1.002	.999	.943	1.092	0.000	.953	.920	.893	.866	.840	.815	.790	29
30	1.001	1.093	.942	.981	0.000	.948	.920	.892	.865	.839	.814	.789	30
31	1.000	0.000	.943	.955	0.000	.947	0.000	.891	0.000	.839	.813	0.000	31
TOTAL	31.842	29.906	29.722	49.839	30.586	63.381	28.281	28.053	26.332	26.392	25.586	24.017	

TOTAL FOR WATER YEAR = 393.857 CUBIC METERS PER SECOND

= 10.92 MILLIMETERS

77/11/02

JORDAN CONTINUOUS DAILY STREAMFLOW SIMULATION MODEL

THE FOLLOWING ARE ANNUAL TOTALS IN MILLIMETERS

RAINFALL	=	171.03
MOISTURE IN DEPRESSION STORAGE	=	63.65
POTENTIAL EVAPORATION	=	2016.00
ESTIMATED ACTUAL EVAPORATION	=	169.43
EVAPORATION FROM DEPRESSION STORAGE	=	40.07
EVAPORATION FROM A HORIZON STORAGE	=	102.08
EVAPORATION FROM B HORIZON STORAGE	=	27.29
GROUNDWATER RECHARGE	=	2.54

RUNOFF FROM IMPERVIOUS AREAS	=	0.00
SURFACE RUNOFF	=	1.60
INTERFLOW THRU A HORIZON	=	0.00
BASE FLOW	=	9.24
LOSSES THRU SEEPS AND SPRINGS	=	2.07
TOTALL SIMULATED RUNOFF	=	10.92
TOTAL OBSERVED RUNOFF	=	15.55

77/11/02

JORDAN CONTINUOUS DAILY STREAMFLOW SIMULATION MODEL

RAINFALL FOR YEAR 1971

ZERQA RIVER STREAMFLOW SIMULATION

VALUES IN MILLIM

DAY	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	DAY
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1
2	0.000	2.370	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2
3	0.000	.160	0.000	0.000	.620	0.000	4.330	0.000	0.000	0.000	0.000	0.000	3
4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	4
5	0.000	0.000	2.810	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	5
6	0.000	0.000	2.240	0.000	.190	0.000	0.000	0.000	0.000	0.000	0.000	0.000	6
7	0.000	.100	4.870	0.000	7.110	0.000	0.000	0.000	0.000	0.000	0.000	0.000	7
8	0.000	0.000	.840	.120	1.130	0.000	.610	0.000	0.000	0.000	0.000	0.000	8
9	0.000	0.000	1.010	.880	1.970	0.000	0.000	0.000	0.000	0.000	0.000	0.000	9
10	0.000	0.000	2.170	7.220	.150	.570	0.000	0.000	0.000	0.000	0.000	0.000	10
11	0.000	0.000	2.970	.110	.550	3.350	8.430	0.000	0.000	0.000	0.000	0.000	11
12	0.000	0.000	6.560	1.920	6.260	8.990	23.060	0.000	0.000	0.000	0.000	0.000	12
13	.490	0.000	.740	1.370	0.000	8.460	26.410	0.000	0.000	0.000	0.000	0.000	13
14	0.000	.030	0.000	.600	0.000	8.320	10.600	0.000	0.000	0.000	0.000	0.000	14
15	0.000	.100	0.000	7.460	0.000	0.000	9.340	0.000	0.000	0.000	0.000	0.000	15
16	0.000	0.000	0.000	4.890	0.000	0.000	6.790	0.000	0.000	0.000	0.000	0.000	16
17	0.000	0.000	0.000	0.000	0.000	0.000	2.330	0.000	0.000	0.000	0.000	0.000	17
18	0.000	0.000	.130	0.000	.760	0.000	0.000	0.000	0.000	0.000	0.000	0.000	18
19	0.000	0.000	.510	0.000	0.000	.190	0.000	0.000	0.000	0.000	0.000	0.000	19
20	0.000	0.000	.270	2.950	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	20
21	0.000	0.000	0.000	1.000	.210	1.430	0.000	0.000	0.000	0.000	0.000	0.000	21
22	0.000	0.000	0.000	2.710	1.070	0.000	0.000	0.000	0.000	0.000	0.000	0.000	22
23	0.000	0.000	0.000	2.280	7.680	0.000	5.110	0.000	0.000	0.000	0.000	0.000	23
24	0.000	0.000	0.000	.190	.600	0.000	1.400	0.000	0.000	0.000	0.000	0.000	24
25	0.000	0.000	0.000	.240	0.000	.060	0.000	0.000	0.000	0.000	0.000	0.000	25
26	0.000	0.000	.200	1.330	1.300	.080	0.000	0.000	0.000	0.000	0.000	0.000	26
27	0.000	.020	0.000	.570	.800	0.000	0.000	0.000	0.000	0.000	0.000	0.000	27
28	0.000	.260	0.000	.070	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	28
29	1.030	0.000	0.000	4.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	29
30	0.000	12.510	0.000	0.000	0.000	3.020	0.000	0.000	0.000	0.000	0.000	0.000	30
31	0.000	0.000	.020	0.000	0.000	.250	0.000	0.000	0.000	0.000	0.000	0.000	31
TOTAL	1.52	15.55	25.34	39.91	30.42	34.72	98.41	0.00	0.00	0.00	0.00	0.00	

TOTAL FOR WATER YEAR = 245.87 MILLIMETERS

77/11/02

JORDAN CONTINUOUS DAILY STREAMFLOW SIMULATION MODEL

OBSERVED RUNOFF FOR YEAR 1971

ZERQA RIVER STREAMFLOW SIMULATION

VALUES IN CUBIC METERS PER SECOND

DAY	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	DAY
1	1.160	1.000	1.570	1.230	1.040	1.040	.890	.580	.360	.240	.230	.380	1
2	1.160	1.040	1.520	1.230	1.040	1.040	.890	.620	.360	.250	.270	.380	2
3	1.120	1.080	1.270	1.230	1.040	1.000	.850	.550	.360	.250	.240	.380	3
4	1.080	1.080	1.230	1.200	1.040	1.000	1.000	.530	.340	.270	.230	.360	4
5	1.040	1.040	1.270	1.200	1.040	.960	1.000	.490	.340	.270	.230	.360	5
6	.960	1.040	1.270	1.160	1.040	.920	.850	.530	.320	.290	.220	.290	6
7	.810	1.000	1.270	1.120	1.080	.920	.700	.490	.320	.250	.210	.320	7
8	.850	1.040	1.310	1.120	1.230	.890	.620	.440	.340	.270	.210	.340	8
9	.850	1.040	1.310	1.160	1.270	.890	.580	.460	.320	.270	.210	.340	9
10	.890	1.080	1.310	1.230	1.230	.890	.580	.460	.310	.310	.210	.320	10
11	.900	1.080	1.350	8.020	1.200	.920	.580	.480	.320	.320	.220	.270	11
12	.920	1.040	1.310	3.360	1.230	1.040	2.110	.480	.340	.270	.210	.340	12
13	1.000	1.040	1.430	1.680	1.230	1.230	107.000	.440	.320	.290	.210	.310	13
14	1.000	1.080	1.310	1.350	1.520	6.020	54.700	.440	.310	.270	.220	.320	14
15	1.000	1.120	1.310	1.340	1.230	5.770	41.800	.440	.310	.250	.220	.320	15
16	1.000	1.080	1.270	12.700	1.120	4.250	29.100	.420	.310	.240	.220	.310	16
17	1.000	1.120	1.310	3.090	1.120	.430	18.600	.410	.270	.230	.220	.310	17
18	.960	1.120	1.310	1.600	1.080	1.230	4.530	.410	.290	.270	.210	.270	18
19	1.040	1.080	1.310	1.270	1.040	1.080	2.340	.400	.250	.240	.210	.270	19
20	1.000	1.080	1.270	1.230	1.040	1.040	1.520	.410	.240	.240	.230	.310	20
21	1.000	1.120	1.270	1.660	1.040	.960	1.270	.410	.250	.230	.230	.320	21
22	.960	1.120	1.270	3.330	1.040	.810	1.080	.410	.270	.240	.230	.340	22
23	.960	1.120	1.270	1.680	1.120	.810	1.040	.410	.270	.240	.230	.320	23
24	.960	1.120	1.230	1.270	1.430	.660	1.200	.380	.270	.240	.230	.310	24
25	.960	1.080	1.230	1.160	1.350	.620	1.230	.380	.270	.240	.230	.320	25
26	.960	1.040	1.230	1.080	1.160	.620	1.040	.340	.270	.230	.230	.340	26
27	1.040	1.080	1.230	1.040	1.160	.580	.930	.360	.250	.240	.240	.340	27
28	1.000	1.120	1.270	1.040	1.000	.810	.730	.360	.250	.250	.230	.310	28
29	1.040	1.200	1.270	1.080	0.000	.890	.660	.360	.240	.270	.230	.340	29
30	1.040	1.230	1.230	1.040	0.000	.960	.620	.340	.250	.240	.250	.340	30
31	1.040	0.000	1.230	1.040	0.000	1.160	0.000	.340	0.000	.230	.160	0.000	31
TOTAL	30.700	32.510	40.240	62.940	32.240	41.440	280.040	13.570	8.920	7.940	6.920	9.780	

TOTAL FOR WATER YEAR = 567.240 CUBIC METERS PER SECOND

= 15.73 MILLIMETERS

SIMULATED RUNOFF FOR ZERQA RIVER STREAMFLOW SIMULATION

WATER YEAR 1971

DAY	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	DAY
1	.788	.764	2.889	.731	.732	.704	.698	.900	.873	.847	.821	.796	1
2	.787	.766	1.278	.731	.722	.703	.691	.899	.872	.846	.820	.795	2
3	.787	.772	.875	.730	.718	.702	.750	.898	.871	.845	.819	.794	3
4	.786	.762	.774	.729	.718	.701	.953	.897	.870	.844	.818	.793	4
5	.785	.761	.754	.728	.717	.701	.755	.896	.869	.843	.818	.793	5
6	.784	.760	.784	.728	.716	.700	.785	.896	.868	.843	.817	.792	6
7	.783	.760	.877	.727	.830	.699	.692	.895	.867	.842	.816	.791	7
8	.783	.759	1.021	.726	1.224	.699	.687	.894	.866	.841	.815	.790	8
9	.782	.758	.810	.726	.851	.698	.687	.893	.866	.840	.814	.789	9
10	.781	.757	.762	.919	.754	.697	.686	.892	.865	.839	.814	.789	10
11	.780	.757	.791	1.581	.726	.717	.867	.891	.864	.838	.813	.788	11
12	.780	.756	1.152	.949	.926	1.019	4.660	.890	.863	.837	.812	.787	12
13	.779	.755	2.127	.829	1.610	2.251	26.794	.889	.862	.837	.811	.786	13
14	.778	.754	1.112	.766	.937	3.935	61.025	.888	.861	.836	.810	.786	14
15	.777	.754	.832	1.057	.769	4.639	37.034	.888	.860	.835	.809	.785	15
16	.776	.753	.763	2.338	.726	1.686	27.250	.887	.860	.834	.809	.784	16
17	.776	.752	.745	1.881	.715	.947	15.923	.886	.859	.833	.808	.783	17
18	.775	.751	.739	1.014	.711	.763	5.236	.885	.858	.832	.807	.782	18
19	.774	.750	.742	.797	.710	.716	1.940	.884	.857	.832	.806	.782	19
20	.773	.750	.750	.752	.710	.704	1.126	.883	.856	.831	.805	.781	20
21	.773	.749	.739	.771	.709	.700	.930	.882	.855	.830	.805	.780	21
22	.772	.748	.738	.756	.708	.699	.887	.881	.854	.829	.804	.779	22
23	.771	.748	.738	.814	.849	.698	1.198	.880	.854	.828	.803	.778	23
24	.770	.747	.737	.761	1.334	.698	2.290	.880	.853	.827	.802	.778	24
25	.770	.746	.736	.733	.864	.697	1.304	.879	.852	.827	.801	.777	25
26	.769	.745	.736	.723	.745	.696	1.003	.878	.851	.826	.801	.776	26
27	.768	.745	.735	.722	.716	.696	.928	.877	.850	.825	.800	.775	27
28	.767	.744	.734	.722	.707	.695	.909	.876	.849	.824	.799	.775	28
29	.767	.743	.734	.767	0.000	.694	.902	.875	.848	.823	.798	.774	29
30	.766	1.228	.733	.923	0.000	.699	.901	.874	.848	.823	.797	.773	30
31	.765	0.000	.732	.771	0.000	.718	0.000	.873	0.000	.822	.797	0.000	31
TOTAL	24.072	23.092	28.670	27.902	23.157	32.073	200.414	27.486	25.800	25.859	25.069	23.532	

TOTAL FOR WATER YEAR = 487.127 CUBIC METERS PER SECOND

= 13.51 MILLIMETERS

77/11/02

JORDAN CONTINUOUS DAILY STREAMFLOW SIMULATION MODEL

THE FOLLOWING ARE ANNUAL TOTALS IN MILLIMETERS

RAINFALL	=	245.87
MOISTURE IN DEPRESSION STORAGE	=	85.99
POTENTIAL EVAPORATION	=	1782.85
ESTIMATED ACTUAL EVAPORATION	=	219.97
EVAPORATION FROM DEPRESSION STORAGE	=	57.51
EVAPORATION FROM A HORIZON STORAGE	=	124.74
EVAPORATION FROM B HORIZON STORAGE	=	37.72
GROUNDWATER RECHARGE	=	7.45

RUNOFF FROM IMPERVIOUS AREAS	=	0.00
SURFACE RUNOFF	=	5.61
INTERFLOW THRU A HORIZON	=	0.00
BASE FLOW	=	7.90
LOSSES THRU SEEPS AND SPRINGS	=	6.10
TOTALL SIMULATED RUNOFF	=	13.51
TOTAL OBSERVED RUNOFF	=	15.73

77/11/02 JORDAN CONTINUOUS DAILY STREAMFLOW SIMULATION MODEL

RAINFALL FOR YEAR 1972 ZERQA RIVER STREAMFLOW SIMULATION VALUES IN MILLIM

DAY	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	DAY
1	0.000	0.000	0.000	.080	0.000	0.000	0.000	1.140	0.000	0.000	0.000	0.000	1
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2
3	0.000	0.000	0.000	0.000	2.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3
4	0.000	0.000	0.000	0.000	6.780	0.000	.190	0.000	0.000	0.000	0.000	0.000	4
5	0.000	0.000	9.860	0.000	6.640	0.000	0.000	0.000	0.000	0.000	0.000	0.000	5
6	0.000	0.000	31.310	0.000	14.220	0.000	0.000	0.000	0.000	0.000	0.000	0.000	6
7	0.000	0.000	4.850	0.000	1.710	0.000	0.000	0.000	0.000	0.000	0.000	0.000	7
8	0.000	0.000	8.290	0.000	.570	0.000	2.080	0.000	0.000	0.000	0.000	0.000	8
9	0.000	.090	.230	0.000	0.000	0.000	2.110	0.000	0.000	0.000	0.000	0.000	9
10	0.000	0.000	0.000	0.000	0.000	0.000	3.830	0.000	0.000	0.000	0.000	0.000	10
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	11
12	0.000	0.000	.970	0.000	.530	0.000	0.000	0.000	0.000	0.000	0.000	0.000	12
13	0.000	0.000	6.210	5.330	0.000	.060	.350	0.000	0.000	0.000	0.000	0.000	13
14	0.000	0.000	4.280	7.890	0.000	.280	0.000	0.000	0.000	0.000	0.000	0.000	14
15	0.000	0.000	.620	3.060	0.000	3.180	0.000	0.000	0.000	0.000	0.000	0.000	15
16	0.000	.360	0.000	2.190	2.130	15.610	0.000	0.000	0.000	0.000	0.000	0.000	16
17	0.000	10.910	1.960	.490	2.160	.900	0.000	0.000	0.000	0.000	0.000	0.000	17
18	0.000	2.940	3.550	.050	2.870	0.000	0.000	0.000	0.000	0.000	0.000	0.000	18
19	0.000	0.000	.420	0.000	.450	.730	0.000	0.000	0.000	0.000	0.000	0.000	19
20	0.000	0.000	.590	0.000	0.000	5.360	0.000	0.000	0.000	0.000	0.000	0.000	20
21	0.000	0.000	.470	3.230	0.000	10.260	5.240	0.000	0.000	0.000	0.000	0.000	21
22	0.000	0.000	1.350	1.030	0.000	2.290	0.000	0.000	0.000	0.000	0.000	0.000	22
23	0.000	0.000	.500	.140	0.000	.030	0.000	0.000	0.000	0.000	0.000	0.000	23
24	0.000	0.000	1.290	0.000	0.000	.170	0.000	0.000	0.000	0.000	0.000	0.000	24
25	0.000	0.000	3.480	.100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	25
26	0.000	0.000	3.680	.800	.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	26
27	0.000	0.000	4.180	.180	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	27
28	0.000	0.000	1.790	0.000	0.000	0.000	3.490	.190	0.000	0.000	0.000	0.000	28
29	0.000	0.000	.070	0.000	0.000	0.000	5.910	0.000	0.000	0.000	0.000	0.000	29
30	0.000	0.000	0.000	0.000	0.000	0.000	.530	0.000	0.000	0.000	0.000	0.000	30
31	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	31
TOTAL	0.00	14.30	89.95	24.57	40.27	38.87	23.73	1.33	0.00	0.00	0.00	0.00	

TOTAL FOR WATER YEAR = 241.02 MILLIMETERS

77/11/02 JORDAN CONTINUOUS DAILY STREAMFLOW SIMULATION MODEL

OBSERVED RUNOFF FOR YEAR 1972 ZERQA RIVER STREAMFLOW SIMULATION VALUES IN CUBIC METERS PER SECOND

DAY	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	DAY
1	.620	.680	.800	1.380	1.290	1.380	.680	.770	.270	.220	.380	.420	1
2	.600	.680	.800	1.380	1.290	1.290	.630	.850	.290	.220	.390	.420	2
3	.600	.700	.800	1.290	1.290	1.290	.600	.700	.270	.220	.390	.420	3
4	.650	.700	.830	1.290	1.420	1.240	.600	.580	.260	.230	.400	.420	4
5	.650	.760	.860	1.290	1.420	1.200	.600	.480	.260	.230	.400	.420	5
6	.600	.800	2.070	1.290	2.720	1.200	.560	.500	.270	.230	.410	.420	6
7	.630	.760	32.400	1.240	11.100	1.200	.580	.480	.240	.240	.420	.420	7
8	.620	.760	8.550	1.200	2.820	1.200	.580	.440	.230	.240	.420	.420	8
9	.650	.800	6.860	1.203	2.550	1.110	20.300	.420	.270	.250	.430	.420	9
10	.620	.760	1.600	1.200	1.720	1.110	3.890	.420	.240	.250	.440	.420	10
11	.620	.760	1.240	1.200	1.600	1.020	5.060	.410	.270	.260	.440	.420	11
12	.620	.800	1.110	1.200	1.600	1.020	1.850	.410	.260	.260	.450	.420	12
13	.580	.830	1.110	1.240	2.370	1.020	1.110	.400	.260	.270	.450	.420	13
14	.620	.830	3.560	2.213	2.100	1.110	.830	.400	.240	.280	.450	.420	14
15	.650	.830	3.430	3.200	1.660	1.110	.760	.360	.230	.280	.460	.420	15
16	.620	.800	1.420	3.600	1.600	1.240	.680	.340	.240	.290	.420	.420	16
17	.600	.990	1.240	1.720	1.600	1.660	.760	.340	.230	.290	.420	.420	17
18	.620	1.110	1.380	1.850	1.970	1.600	.760	.320	.240	.300	.420	.420	18
19	.680	1.060	2.040	1.470	1.910	1.380	.760	.320	.240	.300	.420	.420	19
20	.700	1.020	1.420	1.380	1.660	1.200	.760	.320	.230	.310	.420	.420	20
21	.700	1.020	1.240	1.293	1.600	11.200	.830	.320	.230	.320	.420	.420	21
22	.700	1.020	1.200	1.420	1.600	9.220	1.020	.290	.230	.320	.420	.420	22
23	.700	.990	1.240	1.420	1.600	2.370	.990	.270	.230	.330	.420	.420	23
24	.700	.960	1.200	1.340	1.600	1.290	.920	.310	.240	.330	.420	.420	24
25	.680	.920	1.200	1.340	1.540	1.110	.800	.310	.230	.340	.420	.420	25
26	.680	.890	1.200	1.340	1.470	1.060	.760	.310	.220	.350	.420	.420	26
27	.680	.860	1.420	1.340	1.420	1.020	.700	.320	.220	.350	.420	.420	27
28	.700	.860	1.600	1.290	1.380	.960	.700	.290	.230	.360	.420	.420	28
29	.700	.860	1.540	1.293	1.380	.860	.760	.310	.230	.360	.420	.420	29
30	.700	.860	1.420	1.290	0.000	.760	1.020	.290	.230	.370	.420	.420	30
31	.650	0.000	1.380	1.290	0.000	.700	0.000	.260	0.000	.380	.420	0.000	31
TOTAL	20.110	25.670	88.160	46.560	59.280	55.130	58.870	12.540	7.330	8.980	13.050	12.600	

TOTAL FOR WATER YEAR = 400.200 CUBIC METERS PER SECOND

= 11.10 MILLIMETERS

SIMULATED RUNOFF FOR ZERQA RIVER STREAMFLOW SIMULATION WATER YEAR 1972

DAY	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	DAY
1	.772	.749	.728	.899	.918	.981	1.000	1.053	.941	.913	.885	.858	1
2	.772	.748	.727	.895	.917	.980	.999	.991	.940	.912	.885	.858	2
3	.771	.747	.726	.895	.925	.979	.998	.974	.939	.912	.884	.857	3
4	.770	.746	.726	.898	1.178	.978	.997	.968	.938	.911	.883	.856	4
5	.769	.746	1.047	.899	2.118	.977	.996	.967	.937	.910	.882	.855	5
6	.768	.745	7.700	.901	3.875	.976	.995	.966	.937	.909	.881	.854	6
7	.768	.744	26.213	.902	9.014	.975	.994	.965	.936	.908	.880	.853	7
8	.767	.743	11.480	.902	3.060	.974	1.002	.964	.935	.907	.879	.852	8
9	.766	.743	11.365	.902	1.473	.973	1.033	.963	.934	.906	.878	.852	9
10	.765	.742	3.411	.902	1.079	.972	1.024	.962	.933	.905	.878	.851	10
11	.765	.741	1.425	.902	.983	.971	1.070	.961	.932	.904	.877	.850	11
12	.764	.741	.932	.901	1.629	.970	1.009	.960	.931	.903	.876	.849	12
13	.763	.740	1.250	.995	3.906	.969	.993	.959	.930	.902	.875	.848	13
14	.762	.739	3.103	1.680	1.701	.968	.987	.958	.929	.902	.874	.847	14
15	.762	.738	2.995	2.737	1.151	.997	.986	.957	.928	.901	.873	.847	15
16	.761	.738	1.383	1.794	1.029	2.247	.985	.956	.927	.900	.872	.846	16
17	.760	1.086	.955	1.256	1.103	6.082	.984	.955	.926	.899	.871	.845	17
18	.759	2.316	1.047	.999	1.334	2.255	.983	.954	.925	.898	.871	.844	18
19	.759	1.282	1.563	.935	1.384	1.295	.982	.954	.924	.897	.870	.843	19
20	.758	.872	1.006	.920	1.087	1.163	.981	.953	.923	.896	.869	.842	20
21	.757	.769	.870	.952	1.013	2.503	1.073	.952	.923	.895	.868	.841	21
22	.756	.743	.870	1.090	.995	5.725	1.389	.951	.922	.894	.867	.841	22
23	.755	.734	.971	1.005	.988	2.386	1.081	.950	.921	.893	.866	.840	23
24	.755	.733	.872	.941	.987	1.346	1.003	.949	.920	.893	.865	.839	24
25	.754	.732	.975	.925	.986	1.088	.983	.948	.919	.892	.864	.838	25
26	.753	.731	1.541	.921	.985	1.025	.975	.947	.918	.891	.864	.837	26
27	.752	.731	1.991	.920	.984	1.008	.974	.946	.917	.890	.863	.836	27
28	.752	.730	2.557	.920	.983	1.003	.984	.945	.916	.889	.862	.836	28
29	.751	.729	1.578	.920	.982	1.002	1.089	.944	.915	.888	.861	.835	29
30	.750	.729	1.055	.920	0.000	1.001	1.299	.943	.914	.887	.860	.834	30
31	.749	0.000	.928	.919	0.000	1.001	0.000	.942	0.000	.886	.859	0.000	31
TOTAL	23.585	24.807	93.990	32.556	48.767	46.771	30.841	29.758	27.831	27.894	27.042	25.303	

TOTAL FOR WATER YEAR = 439.224 CUBIC METERS PER SECOND

= 12.18 MILLIMETERS

77/11/02

JORDAN CONTINUOUS DAILY STREAMFLOW SIMULATION MODEL

THE FOLLOWING ARE ANNUAL TOTALS IN MILLIMETERS

RAINFALL	=	241.02
MOISTURE IN DEPRESSION STORAGE	=	86.64
POTENTIAL EVAPORATION	=	1962.45
ESTIMATED ACTUAL EVAPORATION	=	221.55
EVAPORATION FROM DEPRESSION STORAGE	=	43.98
EVAPORATION FROM A HORIZON STORAGE	=	130.70
EVAPORATION FROM B HORIZON STORAGE	=	46.87
GROUNDWATER RECHARGE	=	10.67

RUNOFF FROM IMPERVIOUS AREAS	=	0.00
SURFACE RUNOFF	=	3.19
INTERFLOW THRU A HORIZON	=	0.00
BASE FLOW	=	8.99
LOSSES THRU SEEPS AND SPRINGS	=	0.73
TOTALL SIMULATED RUNOFF	=	12.18
TOTAL OBSERVED RUNOFF	=	11.18

77/11/02 JORDAN CONTINUOUS DAILY STREAMFLOW SIMULATION MODEL

RAINFALL FOR YEAR 1973 ZERQA RIVER STREAMFLOW SIMULATION VALUES IN MILLIMETERS

DAY	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	DAY
1	0.000	0.000	0.000	0.000	2.640	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1
2	0.000	1.570	0.000	0.000	0.000	5.510	0.000	0.000	0.000	0.000	0.000	0.000	2
3	0.000	1.490	.050	0.000	0.000	7.240	0.000	0.000	0.000	0.000	0.000	0.000	3
4	0.000	.980	.610	0.000	.080	.190	0.000	0.000	0.000	0.000	0.000	0.000	4
5	0.000	0.000	0.000	0.000	.090	1.670	0.000	0.000	0.000	0.000	0.000	0.000	5
6	0.000	0.000	0.000	0.000	0.000	11.550	0.000	0.000	0.000	0.000	0.000	0.000	6
7	0.000	0.000	0.000	0.000	0.000	6.450	.420	.190	0.000	0.000	0.000	0.000	7
8	0.000	0.000	0.000	0.000	0.000	0.000	3.390	0.000	0.000	0.000	0.000	0.000	8
9	0.000	0.000	.020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	9
10	0.000	0.000	.040	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	10
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	11
12	0.000	0.000	0.000	4.450	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	12
13	0.000	0.000	0.000	5.810	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	13
14	0.000	0.000	0.000	15.370	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	14
15	0.000	0.000	0.000	17.860	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	15
16	0.000	0.000	0.000	4.160	0.000	0.000	0.000	.350	0.000	0.000	0.000	0.000	16
17	.160	0.000	0.000	.090	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	17
18	0.000	0.000	.350	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	18
19	0.000	0.000	.700	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	19
20	0.000	0.000	.230	.050	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	20
21	0.000	0.000	0.000	0.000	0.000	0.000	.730	0.000	0.000	0.000	0.000	0.000	21
22	0.000	0.000	0.000	0.000	9.970	.090	0.000	0.000	0.000	0.000	0.000	0.000	22
23	0.000	0.000	0.000	0.000	4.950	0.000	0.000	0.000	0.000	0.000	0.000	0.000	23
24	0.000	25.490	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	24
25	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	25
26	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	26
27	0.000	.250	0.000	.740	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	27
28	0.000	.510	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	28
29	0.000	2.220	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	29
30	0.000	0.000	0.000	2.140	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	30
31	.030	0.000	0.000	5.720	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	31
TOTAL	.19	32.51	2.00	56.39	17.73	33.50	4.54	.54	0.00	0.00	0.00	0.00	

TOTAL FOR WATER YEAR = 147.40 MILLIMETERS

77/11/02

JORDAN CONTINUOUS DAILY STREAMFLOW SIMULATION MODEL

OBSERVED RUNOFF FOR YEAR 1973

ZERQA RIVER STREAMFLOW SIMULATION

VALUES IN CUBIC METERS PER SECOND

DAY	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	DAY
1	.360	.490	.770	.550	1.940	.830	.490	.650	.580	.520	.460	.390	1
2	.330	.520	.650	.550	1.240	.710	.490	.550	.580	.520	.450	.390	2
3	.310	.590	.620	.520	1.120	1.120	.490	.520	.570	.510	.450	.390	3
4	.390	.650	.620	.550	1.060	1.960	.520	.520	.570	.510	.450	.380	4
5	.390	.710	.710	.550	1.060	1.240	.520	.520	.570	.510	.450	.390	5
6	.430	.650	.770	.520	1.000	1.240	.550	.550	.570	.510	.450	.380	6
7	.390	.550	.710	.550	.890	2.870	.550	.590	.570	.510	.440	.380	7
8	.360	.590	.650	.590	.890	8.650	.620	.520	.560	.500	.440	.380	8
9	.430	.550	.590	.550	.890	2.430	.620	.590	.560	.500	.440	.380	9
10	.390	.550	.550	.590	.730	1.500	.460	.490	.560	.500	.440	.380	10
11	.330	.620	.550	.520	.770	1.320	.390	.460	.560	.500	.440	.370	11
12	.330	.620	.520	.620	.770	1.120	.360	.490	.560	.500	.430	.370	12
13	.330	.620	.550	.820	.710	1.000	.330	.550	.550	.490	.430	.370	13
14	.360	.620	.550	2.580	.710	.940	.390	.460	.550	.490	.430	.370	14
15	.390	.590	.520	6.280	.550	.940	.430	.460	.550	.490	.430	.370	15
16	.430	.590	.520	4.180	.710	.890	.550	.520	.550	.490	.430	.360	16
17	.430	.620	.550	10.400	.650	.830	.590	.550	.550	.490	.430	.360	17
18	.390	.620	.550	5.370	.620	.770	.550	.550	.540	.480	.420	.360	18
19	.390	.590	.550	1.670	.590	.620	.550	.550	.540	.480	.420	.360	19
20	.390	.550	.620	1.120	.550	.650	.520	.490	.540	.480	.420	.360	20
21	.390	.520	.620	1.000	.620	.770	.620	.390	.540	.480	.420	.350	21
22	.430	.520	.590	.940	.710	.710	.520	.390	.540	.480	.410	.350	22
23	.460	.520	.550	.890	1.550	.650	.550	.310	.530	.470	.410	.350	23
24	.430	.620	.550	.890	1.410	.590	.490	.390	.530	.470	.410	.350	24
25	.430	7.760	.550	.890	1.180	.620	.430	.390	.530	.470	.410	.350	25
26	.460	2.830	.590	.830	1.060	.550	.460	.460	.530	.470	.410	.340	26
27	.490	1.240	.590	.830	.940	.550	.460	.460	.530	.470	.400	.340	27
28	.520	.940	.590	.830	.890	.550	.520	.590	.520	.460	.400	.340	28
29	.550	.830	.550	.890	0.000	.520	.430	.580	.520	.460	.400	.340	29
30	.550	.770	.550	.890	0.000	.460	.430	.580	.520	.460	.400	.340	30
31	.520	0.000	.550	1.120	0.000	.460	0.000	.580	0.000	.460	.400	0.000	31
TOTAL	12.780	28.440	18.400	49.080	25.810	38.140	14.880	15.700	16.470	15.130	13.220	10.940	

TOTAL FOR WATER YEAR = 258.990 CUBIC METERS PER SECOND

= 7.18 MILLIMETERS

SIMULATED RUNOFF FOR ZERQA RIVER STREAMFLOW SIMULATION WATER YEAR 1973

DAY	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	DAY
1	.833	.808	.856	.773	1.472	.798	.791	.768	.745	.723	.700	.679	1
2	.832	.807	.810	.772	1.051	.851	.791	.767	.744	.722	.700	.678	2
3	.831	.809	.798	.771	.873	1.273	.790	.766	.743	.721	.699	.678	3
4	.831	.810	.794	.771	.828	1.903	.789	.766	.742	.720	.698	.677	4
5	.830	.808	.794	.770	.816	1.874	.788	.765	.742	.720	.698	.676	5
6	.829	.804	.793	.769	.812	1.577	.787	.764	.741	.719	.697	.676	6
7	.828	.803	.792	.768	.811	4.355	.787	.763	.740	.718	.696	.675	7
8	.827	.802	.792	.768	.810	3.432	.805	.763	.739	.718	.696	.674	8
9	.826	.801	.791	.767	.809	1.464	.870	.762	.739	.717	.695	.674	9
10	.826	.800	.790	.766	.808	.972	.806	.761	.738	.716	.694	.673	10
11	.825	.800	.789	.765	.808	.849	.789	.760	.737	.715	.694	.672	11
12	.824	.799	.789	.852	.807	.818	.783	.760	.736	.715	.693	.672	12
13	.823	.798	.788	1.303	.806	.807	.782	.759	.736	.714	.692	.671	13
14	.822	.797	.787	3.178	.805	.806	.781	.758	.735	.713	.691	.670	14
15	.821	.796	.786	12.811	.804	.805	.780	.757	.734	.712	.691	.670	15
16	.821	.796	.785	23.526	.804	.804	.780	.757	.733	.712	.690	.669	16
17	.820	.795	.785	8.614	.803	.803	.779	.756	.733	.711	.689	.668	17
18	.819	.794	.784	2.751	.802	.803	.778	.755	.732	.710	.689	.668	18
19	.818	.793	.783	1.289	.801	.802	.777	.754	.731	.710	.688	.667	19
20	.817	.792	.782	.927	.800	.801	.777	.754	.731	.709	.687	.666	20
21	.817	.792	.782	.839	.800	.800	.776	.753	.730	.708	.687	.666	21
22	.816	.791	.781	.819	1.145	.799	.775	.752	.729	.708	.686	.665	22
23	.815	.790	.780	.814	2.460	.799	.774	.751	.728	.707	.685	.664	23
24	.814	3.341	.779	.816	1.799	.798	.773	.751	.728	.706	.685	.664	24
25	.813	12.070	.778	.816	1.058	.797	.773	.750	.727	.705	.684	.663	25
26	.812	3.612	.778	.816	.862	.796	.772	.749	.726	.705	.683	.662	26
27	.812	1.498	.777	.816	.815	.795	.771	.748	.725	.704	.682	.662	27
28	.811	.970	.776	.816	.802	.795	.770	.748	.725	.703	.682	.661	28
29	.810	.891	.775	.816	0.000	.794	.770	.747	.724	.703	.681	.660	29
30	.809	1.040	.775	.817	0.000	.793	.769	.746	.723	.702	.680	.660	30
31	.808	0.000	.774	.967	0.000	.792	0.000	.745	0.000	.701	.680	0.000	31
TOTAL	25.441	41.815	24.424	72.863	26.872	34.553	23.532	23.455	22.016	22.066	21.392	20.080	

TOTAL FOR WATER YEAR = 358.509 CUBIC METERS PER SECOND

= 9.94 MILLIMETERS

77/11/02

JORDAN CONTINUOUS DAILY STREAMFLOW SIMULATION MODEL

THE FOLLOWING ARE ANNUAL TOTALS IN MILLIMETERS

RAINFALL	=	147.48
MOISTURE IN DEPRESSION STORAGE	=	43.86
POTENTIAL EVAPORATION	=	2123.45
ESTIMATED ACTUAL EVAPORATION	=	144.28
EVAPORATION FROM DEPRESSION STORAGE	=	24.87
EVAPORATION FROM A HORIZON STORAGE	=	89.92
EVAPORATION FROM B HORIZON STORAGE	=	29.48
GROUNDWATER RECHARGE	=	2.88

RUNOFF FROM IMPERVIOUS AREAS	=	0.00
SURFACE RUNOFF	=	2.23
INTERFLOW THRU A HORIZON	=	0.00
BASE FLOW	=	7.71
LOSSES THRU SEEPS AND SPRINGS	=	2.36
TOTALL SIMULATED RUNOFF	=	9.94
TOTAL OBSERVED RUNOFF	=	7.10

STATISTICS	EXPA	EXPB	ERROR	SSERR	SSLOG	ABSV	OBFN	CCOF	SLOPE	YINT
	1.0000	0.0000	5.3717	8.5690	110.7630	29.0841	29.0841	.0418	1.1145	-.0046

THE FOLLOWING IS THE FIXED AND INITIAL PARAMETER VALUES

PARAMETER	BSMI	BGWR	WCEPT	SQKM	FRUK	SGWK	PGWK	SROK	PIMP	TRLOS
FIXED VALUE	20.000	2.700	4.000	652.000	.300	.975	.999	.225	0.000	0.000

PARAMETER	FMAX	FMIN	ALFN	AHORD	BHORP	FSRO	REKP	BHORD	EPAR	DLOSS
INITIAL VALUE	420.000	30.000	.100	50.000	10.000	.100	1.000	90.000	.500	0.000
UPPER LIMIT	600.000	60.000	.400	100.000	50.000	.150	4.000	200.000	1.000	.800
LOWER LIMIT	300.000	10.000	.050	20.000	5.000	.100	1.000	60.000	.500	0.000
INCREMENT	10.000	2.000	.010	2.000	2.000	.010	.100	2.000	.050	.050

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PATTERN MOVE

PATTERN MOVE

PATTERN MOVE

PATTERN=   1   RESOLUTION=    0

PATTERN MOVE

PATTERN MOVE

PATTERN MOVE

PATTERN=   2   RESOLUTION=    0

PATTERN MOVE

PATTERN MOVE

PATTERN=   2   RESOLUTION=    1

PATTERN MOVE

PATTERN MOVE

TRIAL  11      RUN 200

OPTIMIZATION CRITERIA (THIS RUN)            15.313736

OPTIMIZATION CRITERIA (BEST PRIOR RUN)      15.259208
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THE FOLLOWING ARE ANNUAL TOTALS IN MILLIMETERS

RAINFALL	=	277.72
MOISTURE IN DEPRESSION STORAGE	=	89.61
POTENTIAL EVAPORATION	=	1962.45
ESTIMATED ACTUAL EVAPORATION	=	192.31
EVAPORATION FROM DEPRESSION STORAGE	=	46.90
EVAPORATION FROM A HORIZON STORAGE	=	117.31
EVAPORATION FROM B HORIZON STORAGE	=	28.09
GROUNDWATER RECHARGE	=	17.31

RUNOFF FROM IMPERVIOUS AREAS	=	0.00
SURFACE RUNOFF	=	12.80
INTERFLOW THRU A HORIZON	=	0.00
BASE FLOW	=	15.91
LOSSES THRU SEEPS AND SPRINGS	=	14.16
TOTALL SIMULATED RUNOFF	=	28.71
TOTAL OBSERVED RUNOFF	=	33.05

THE FOLLOWING IS THE FIXED AND INITIAL PARAMETER VALUES

PARAMETER	BSMI	BGWR	WCEPT	SQKM	FROK	SGWK	PGWK	SROK	PIMP	TRLOS
FIXED VALUE	20.000	2.700	4.030	652.600	.300	.975	.939	.225	0.000	0.000

PARAMETER	FMAX	FMIN	ALFN	AHORD	BHORP	FSRO	REXP	BHORD	EPAR	DLOSS
INITIAL VALUE	420.000	30.000	.130	53.000	10.000	.103	1.000	90.000	.500	0.000
UPPER LIMIT	600.000	60.000	.430	100.000	50.000	.150	4.000	200.000	1.000	.800
LOWER LIMIT	300.000	10.000	.030	20.000	5.000	.100	1.000	60.000	.500	0.000
INCREMENT	5.000	1.000	.015	1.000	1.000	.005	.150	1.000	.025	.025

THE FOLLOWING IS THE FINAL OPTIMIZATION RESULTS

PARAMETER	FMAX	FMIN	ALFN	AHORD	BHORP	FSRO	REXP	BHORD	EPAR	DLOSS
BEST VALUE	315.000	59.000	.230	59.000	16.000	.145	1.500	129.000	.525	.450

STATISTICS	EXPA	EXPB	ERROR	SSERR	SSLOG	ABSV	OBFN	CCOF	SLOPE	YINT
	1.0005	0.0000	5.1306	3.1545	25.5936	15.2892	15.2892	.9201	.9152	.0078

77/11/03

JORDAN CONTINUOUS DAILY STREAMFLOW SIMULATION MODEL

SEIL ZERQA STREAMFLOW SIMULATION

FOLLOWING ARE PARAMETERS AND CONSTANTS FOR YEAR(S) 1972-1973

BSMI	BGWF	FMAX	FMIN	AHORD	BHORP	BHORD	REXP	WCEPT	SQKM
20.00	2.70	315.00	59.00	59.00	16.00	129.00	1.50	4.00	652.00

EPAR	FSFO	SFOK	FROK	SGWK	PGWK	ALFN	DLOSS	PIMP	TRLOS
.525	.145	.225	.300	.975	.999	.230	.450	0.000	0.000

200

77/11/03 JORDAN CONTINUOUS DAILY STREAMFLOW SIMULATION MODEL

PAN EVAPORATION FOR YEAR 1972 SEIL ZERQA STREAMFLOW SIMULATION VALUES IN MILLIMETERS

DAY	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	DAY
1	7.000	5.000	4.000	1.000	5.000	2.000	6.000	3.000	9.000	12.000	12.000	10.000	1
2	7.000	5.000	7.000	1.000	2.000	8.000	8.000	9.000	8.000	12.000	13.000	10.000	2
3	9.000	5.000	4.000	3.000	1.000	7.000	7.000	7.000	10.000	17.000	15.000	8.000	3
4	8.000	4.000	4.000	3.000	0.000	8.000	4.000	8.000	9.000	18.000	15.000	10.000	4
5	7.000	7.000	2.000	2.000	2.000	4.000	5.000	6.000	9.000	11.000	15.000	10.000	5
6	8.000	4.000	6.000	2.000	1.000	2.000	12.000	6.000	11.000	10.000	13.000	10.000	6
7	11.000	3.000	0.000	2.000	1.000	5.000	15.000	6.000	12.000	9.000	10.000	17.000	7
8	8.000	4.000	0.000	2.000	1.000	4.000	1.000	9.000	10.000	11.000	10.000	8.000	8
9	14.000	4.000	3.000	5.000	1.000	4.000	3.000	6.000	11.000	15.000	11.000	9.000	9
10	13.000	4.000	4.000	2.000	3.000	5.000	3.000	5.000	10.000	16.000	11.000	11.000	10
11	9.000	5.000	3.000	4.000	7.000	6.000	4.000	8.000	9.000	14.000	11.000	11.000	11
12	7.000	3.000	2.000	4.000	2.000	5.000	7.000	7.000	9.000	11.000	13.000	8.000	12
13	6.000	9.000	2.000	2.000	2.000	5.000	5.000	6.000	10.000	12.000	11.000	7.000	13
14	12.000	10.000	0.000	1.000	4.000	3.000	12.000	9.000	12.000	15.000	12.000	9.000	14
15	10.000	4.000	0.000	0.000	3.000	1.000	4.000	10.000	12.000	13.000	12.000	10.000	15
16	9.000	4.000	1.000	1.000	2.000	1.000	6.000	11.000	15.000	12.000	13.000	16.000	16
17	8.000	5.000	2.000	1.000	0.000	1.000	5.000	12.000	16.000	11.000	15.000	15.000	17
18	6.000	1.000	1.000	2.000	1.000	2.000	6.000	12.000	15.000	11.000	12.000	12.000	18
19	7.000	3.000	1.000	4.000	1.000	4.000	6.000	11.000	19.000	11.000	12.000	11.000	19
20	6.000	6.000	1.000	3.000	3.000	4.000	9.000	11.000	12.000	11.000	13.000	9.000	20
21	7.000	6.000	2.000	2.000	8.000	1.000	1.000	12.000	12.000	11.000	11.000	11.000	21
22	4.000	5.000	0.000	6.000	10.000	1.000	4.000	12.000	10.000	12.000	10.000	8.000	22
23	5.000	4.000	2.000	1.000	10.000	3.000	6.000	8.000	12.000	12.000	11.000	9.000	23
24	5.000	8.000	2.000	4.000	7.000	3.000	5.000	9.000	11.000	13.000	11.000	8.000	24
25	5.000	3.000	1.000	1.000	7.000	6.000	7.000	8.000	14.000	12.000	9.000	8.000	25
26	4.000	3.000	1.000	1.000	12.000	4.000	10.000	8.000	13.000	11.000	10.000	10.000	26
27	6.000	4.000	0.000	3.000	3.000	8.000	13.000	10.000	12.000	9.000	11.000	10.000	27
28	5.000	3.000	0.000	1.000	3.000	5.000	13.000	9.000	10.000	10.000	12.000	10.000	28
29	6.000	6.000	0.000	2.000	5.000	3.000	4.000	7.000	13.000	11.000	10.000	10.000	29
30	5.000	3.000	2.000	4.000	0.000	4.000	4.000	12.000	12.000	10.000	9.000	14.000	30
31	6.000	0.000	2.000	6.000	0.000	6.000	0.000	9.000	0.000	10.000	9.000	0.000	31
TOTAL	230.00	140.00	59.00	76.00	107.00	125.00	198.00	266.00	347.00	373.00	362.00	309.00	

TOTAL FOR WATER YEAR = 2586.00 MILLIMETERS

77/11/03 JORDAN CONTINUOUS DAILY STREAMFLOW SIMULATION MODEL

RAINFALL FOR YEAR 1972 SEIL ZERQA STREAMFLOW SIMULATION VALUES IN MILLIMETER

DAY	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	DAY
1	0.000	0.000	0.000	.290	0.000	0.000	0.000	2.530	0.000	0.000	0.000	0.000	1
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2
3	0.000	0.000	0.000	0.000	.560	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3
4	0.000	0.000	0.000	0.000	8.640	0.000	0.000	0.000	0.000	0.000	0.000	0.000	4
5	0.000	0.000	11.470	0.000	6.540	0.000	0.000	0.000	0.000	0.000	0.000	0.000	5
6	0.000	0.000	35.170	0.000	16.310	0.000	0.000	0.000	0.000	0.000	0.000	0.000	6
7	0.000	0.000	8.770	0.000	2.540	0.000	0.000	0.000	0.000	0.000	0.000	0.000	7
8	0.000	0.000	6.970	0.000	1.120	0.000	.150	0.000	0.000	0.000	0.000	0.000	8
9	0.000	.070	.470	0.000	0.000	0.000	1.540	0.000	0.000	0.000	0.000	0.000	9
10	0.000	0.000	0.000	0.000	0.000	0.000	4.670	0.000	0.000	0.000	0.000	0.000	10
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	11
12	0.000	0.000	2.500	0.000	6.960	0.000	0.000	0.000	0.000	0.000	0.000	0.000	12
13	0.000	0.000	8.350	9.500	0.000	.020	.710	0.000	0.000	0.000	0.000	0.000	13
14	0.000	0.000	5.570	8.940	0.000	.560	0.000	0.000	0.000	0.000	0.000	0.000	14
15	0.000	0.000	.700	2.920	0.000	2.300	0.000	0.000	0.000	0.000	0.000	0.000	15
16	0.000	.680	0.000	3.860	2.240	16.410	0.000	0.000	0.000	0.000	0.000	0.000	16
17	0.000	16.340	3.730	.090	3.250	1.010	0.000	0.000	0.000	0.000	0.000	0.000	17
18	0.000	3.260	4.080	0.000	2.580	0.000	0.000	0.000	0.000	0.000	0.000	0.000	18
19	0.000	0.000	.470	0.000	.470	2.720	0.000	0.000	0.000	0.000	0.000	0.000	19
20	0.000	0.000	.270	0.000	0.000	6.510	0.000	0.000	0.000	0.000	0.000	0.000	20
21	0.000	0.000	.370	3.110	0.000	8.960	7.720	0.000	0.000	0.000	0.000	0.000	21
22	0.000	0.000	1.680	.860	0.000	1.960	0.000	0.000	0.000	0.000	0.000	0.000	22
23	0.000	0.000	.950	.280	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	23
24	0.000	0.000	1.360	0.000	0.000	.210	0.000	0.000	0.000	0.000	0.000	0.000	24
25	0.000	0.000	2.220	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	25
26	0.000	0.000	3.510	.650	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	26
27	0.000	0.000	3.560	.380	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	27
28	0.000	0.000	2.130	0.000	0.000	0.000	4.450	.720	0.000	0.000	0.000	0.000	28
29	0.000	0.000	.030	0.000	0.000	0.000	5.100	0.000	0.000	0.000	0.000	0.000	29
30	0.000	0.000	0.000	0.000	0.000	0.000	.740	0.000	0.000	0.000	0.000	0.000	30
31	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	31
TOTAL	0.00	20.35	106.35	30.88	51.21	40.60	25.08	3.25	0.00	0.00	0.00	0.00	

TOTAL FOR WATER YEAR = 277.72 MILLIMETERS

77/11/03

JORDAN CONTINUOUS DAILY STREAMFLOW SIMULATION MODEL

OBSERVED RUNOFF FOR YEAR 1972

SEIL ZERQA STREAMFLOW SIMULATION

VALUES IN CUBIC METERS PER SECOND

DAY	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	DAY
1	.020	.020	.020	.560	.780	.450	.450	1.280	.670	.400	.310	.220	1
2	.020	.020	.320	.670	.760	.430	.400	1.280	.650	.390	.300	.210	2
3	.020	.020	.020	.550	.760	.400	.400	1.240	.630	.390	.300	.210	3
4	.020	.020	.020	.550	1.210	.400	.380	1.220	.610	.390	.300	.210	4
5	.020	.020	.020	.530	1.210	.370	.380	1.200	.590	.380	.290	.200	5
6	.020	.020	7.010	.530	5.990	.350	.360	1.180	.570	.380	.290	.200	6
7	.020	.020	28.300	.510	7.920	.350	.360	1.160	.550	.380	.290	.200	7
8	.020	.020	4.010	.510	1.430	.340	.340	1.140	.530	.380	.280	.190	8
9	.020	.020	2.500	.510	1.320	.330	.560	1.120	.510	.370	.280	.190	9
10	.020	.020	.210	.480	.540	.330	1.210	1.100	.510	.370	.280	.190	10
11	.020	.020	.210	.480	.480	.320	3.120	1.080	.480	.370	.280	.190	11
12	.020	.020	.320	.480	.480	.320	1.600	1.060	.480	.360	.270	.180	12
13	.020	.020	.320	2.270	1.000	.320	.780	1.040	.480	.360	.270	.180	13
14	.020	.020	5.720	4.890	.540	.300	.750	1.020	.470	.360	.270	.180	14
15	.020	.020	.890	1.650	.510	.370	.750	1.000	.470	.360	.260	.170	15
16	.020	.020	.510	1.750	.510	.510	.710	.980	.450	.350	.250	.170	16
17	.020	.400	.450	1.100	.760	1.670	.710	.960	.450	.350	.260	.170	17
18	.020	1.500	.900	1.100	1.060	.670	.670	.940	.430	.350	.250	.160	18
19	.020	.500	1.580	.780	1.000	.560	.670	.920	.430	.340	.250	.160	19
20	.020	.200	.510	.780	.670	.560	.650	.900	.400	.340	.250	.160	20
21	.020	.100	.460	.890	.560	8.960	1.100	.890	.400	.340	.250	.160	21
22	.020	.020	.450	1.000	.560	3.120	2.140	.870	.400	.340	.240	.150	22
23	.020	.020	.450	1.000	.540	1.100	1.440	.850	.400	.330	.240	.150	23
24	.020	.020	.420	1.000	.540	1.000	1.420	.830	.400	.330	.240	.150	24
25	.020	.020	.420	1.000	.510	.890	1.400	.810	.400	.330	.240	.140	25
26	.020	.020	.420	1.000	.510	.890	1.380	.790	.400	.320	.230	.140	26
27	.020	.020	.910	1.000	.510	.780	1.360	.770	.400	.320	.230	.140	27
28	.020	.020	1.000	1.000	.480	.540	1.340	.750	.400	.320	.230	.140	28
29	.020	.020	1.100	.890	.450	.510	1.320	.730	.400	.320	.220	.130	29
30	.020	.020	1.000	.890	0.000	.510	1.300	.710	.400	.310	.220	.130	30
31	.020	0.000	.670	.780	0.000	.450	0.000	.690	0.000	.310	.220	0.000	31
TOTAL	.620	3.200	60.860	31.130	33.590	28.100	29.850	30.510	14.360	10.940	8.110	5.170	

TOTAL FOR WATER YEAR = 255.440 CUBIC METERS PER SECOND

= 33.85 MILLIMETERS

SIMULATED RUNOFF FOR GEIL ZERDA STREAMFLOW SIMULATION

WATER YEAR 1972

DAY	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	DAY
1	.020	.020	.020	.551	.557	.765	.759	.491	.295	.205	.148	.111	1
2	.020	.020	.020	.553	.546	.751	.744	.470	.292	.203	.146	.110	2
3	.020	.020	.020	.554	.539	.737	.730	.451	.288	.200	.145	.109	3
4	.020	.020	.021	.551	.667	.723	.716	.442	.284	.198	.143	.108	4
5	.020	.020	.200	.547	1.309	.710	.703	.434	.280	.196	.142	.107	5
6	.020	.020	6.933	.541	3.401	.697	.690	.428	.277	.194	.141	.106	6
7	.020	.020	28.286	.535	9.567	.684	.678	.421	.273	.192	.139	.105	7
8	.020	.020	10.291	.527	2.885	.672	.665	.415	.270	.189	.138	.104	8
9	.020	.020	5.612	.519	1.264	.659	.654	.409	.266	.187	.137	.103	9
10	.020	.020	1.346	.510	.965	.649	.657	.402	.263	.185	.135	.102	10
11	.020	.020	.397	.502	.829	.636	.693	.397	.260	.183	.134	.102	11
12	.020	.020	.205	.494	1.115	.625	.634	.391	.257	.181	.133	.101	12
13	.020	.020	.658	.611	2.116	.614	.612	.385	.253	.179	.132	.100	13
14	.020	.019	2.464	1.434	1.147	.603	.599	.379	.250	.178	.130	.099	14
15	.020	.019	1.969	2.460	.923	.593	.589	.374	.247	.176	.129	.098	15
16	.020	.019	.643	1.383	.893	1.226	.578	.368	.244	.174	.128	.097	16
17	.020	.377	.412	1.157	1.012	3.339	.568	.363	.241	.172	.127	.097	17
18	.020	1.762	.655	.722	1.314	1.256	.559	.358	.238	.170	.126	.096	18
19	.020	.617	.854	.627	1.156	.795	.549	.353	.236	.168	.124	.095	19
20	.020	.154	.458	.606	.975	.893	.540	.346	.233	.167	.123	.094	20
21	.020	.050	.376	.630	.925	2.053	.623	.343	.230	.165	.122	.094	21
22	.020	.027	.396	.726	.900	3.652	.926	.378	.227	.163	.121	.093	22
23	.020	.022	.492	.664	.861	1.533	.610	.334	.225	.162	.120	.092	23
24	.020	.021	.421	.623	.562	.999	.532	.329	.222	.160	.119	.091	24
25	.020	.020	.437	.611	.545	.881	.508	.325	.219	.158	.118	.091	25
26	.020	.020	.569	.605	.629	.852	.496	.320	.217	.157	.117	.090	26
27	.020	.020	.895	.599	.612	.834	.487	.316	.214	.155	.116	.089	27
28	.020	.020	1.100	.593	.796	.819	.491	.312	.212	.154	.115	.088	28
29	.020	.020	.822	.586	.761	.814	.546	.308	.210	.152	.114	.088	29
30	.020	.020	.597	.577	0.000	.788	.587	.303	.207	.151	.113	.087	30
31	.020	0.000	.554	.567	0.000	.773	0.000	.299	0.000	.149	.112	0.000	31
TOTAL	.622	3.413	67.977	22.167	40.754	31.622	18.723	11.606	7.433	5.424	3.984	2.947	

TOTAL FOR WATER YEAR = 216.663 CUBIC METERS PER SECOND

= 26.71 MILLIMETERS

77/11/03

JORDAN CONTINUOUS DAILY STREAMFLOW SIMULATION MODEL

RAINFALL FOR YEAR 1973

SEIL ZERQA STREAMFLOW SIMULATION

VALUES IN MILLIM

DAY	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	DAY
1	0.000	0.000	0.000	0.000	1.460	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1
2	0.000	2.350	0.000	0.000	0.000	5.600	0.000	0.000	0.000	0.000	0.000	0.000	2
3	0.000	5.860	0.000	0.000	0.000	11.200	0.000	0.000	0.000	0.000	0.000	0.000	3
4	0.000	1.220	1.660	0.000	.320	.120	0.000	0.000	0.000	0.000	0.000	0.000	4
5	0.000	0.000	0.000	0.000	0.000	1.360	0.000	0.000	0.000	0.000	0.000	0.000	5
6	0.000	0.000	0.000	0.000	0.000	14.860	0.000	0.000	0.000	0.000	0.000	0.000	6
7	0.000	0.000	0.000	0.000	0.000	9.000	0.000	0.000	0.000	0.000	0.000	0.000	7
8	0.000	0.000	0.000	0.000	0.000	0.000	3.200	.650	0.000	0.000	0.000	0.000	8
9	0.000	0.000	.050	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	9
10	0.000	0.000	.170	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	10
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	11
12	0.000	0.000	0.000	4.900	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	12
13	0.000	0.000	0.000	16.340	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	13
14	0.000	0.000	0.000	15.405	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	14
15	0.000	0.000	0.000	24.030	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	15
16	0.000	0.000	0.000	2.730	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	16
17	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	17
18	0.000	0.000	.370	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	18
19	0.000	0.000	.210	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	19
20	0.000	0.000	.170	.210	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	20
21	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	21
22	0.000	0.000	0.000	0.000	14.560	1.570	0.000	0.000	0.000	0.000	0.000	0.000	22
23	0.000	0.000	0.000	0.000	5.840	0.000	0.000	0.000	0.000	0.000	0.000	0.000	23
24	0.000	28.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	24
25	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	25
26	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	26
27	0.000	.450	0.000	1.060	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	27
28	0.000	.920	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	28
29	0.000	2.290	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	29
30	0.000	0.000	0.000	3.950	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	30
31	0.000	0.000	0.000	7.790	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	31
TOTAL	0.00	41.36	2.65	76.41	22.18	43.73	3.20	.65	0.00	0.00	0.00	0.00	

TOTAL FOR WATER YEAR = 190.18 MILLIMETERS

77/11/03

JORDAN CONTINUOUS DAILY STREAMFLOW SIMULATION MODEL

OBSERVED RUNOFF FOR YEAR 1973

SEIL ZEROA STREAMFLOW SIMULATION

VALUES IN CUBIC METERS PER SECOND

DAY	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	DAY
1	.130	.120	.230	.130	1.600	1.020	.230	.130	.090	.040	.030	.030	1
2	.130	.120	.230	.120	.600	1.020	.220	.130	.080	.040	.030	.030	2
3	.130	.120	.230	.120	.570	1.020	.210	.130	.080	.040	.030	.030	3
4	.130	.120	.230	.120	.570	1.020	.210	.130	.080	.040	.030	.030	4
5	.130	.120	.230	.120	.570	1.020	.200	.120	.080	.040	.030	.030	5
6	.130	.120	.230	.120	.570	1.020	.190	.120	.080	.040	.030	.030	6
7	.130	.120	.300	.120	.540	4.700	.190	.120	.080	.040	.030	.030	7
8	.130	.120	.300	.120	.600	7.900	.180	.120	.080	.040	.030	.030	8
9	.130	.120	.290	.120	.600	6.000	.180	.120	.080	.030	.030	.030	9
10	.130	.120	.280	.120	.600	.350	.180	.120	.070	.030	.030	.030	10
11	.130	.120	.270	.130	.600	.340	.170	.120	.070	.030	.030	.030	11
12	.130	.080	.260	.140	.600	.340	.170	.110	.070	.030	.030	.030	12
13	.130	.080	.260	.750	.600	.330	.160	.110	.070	.030	.030	.030	13
14	.130	.080	.250	2.000	.600	.320	.160	.110	.070	.030	.030	.030	14
15	.130	.080	.240	3.690	.600	.320	.160	.110	.070	.030	.030	.030	15
16	.130	.080	.240	3.300	.600	.310	.150	.110	.060	.030	.030	.030	16
17	.130	.080	.230	8.920	.600	.300	.150	.110	.060	.030	.030	.030	17
18	.130	.080	.220	1.360	.600	.300	.140	.110	.060	.030	.030	.030	18
19	.130	.080	.210	.800	.600	.290	.140	.110	.060	.030	.030	.030	19
20	.130	.080	.200	.240	.600	.280	.130	.100	.060	.030	.030	.030	20
21	.130	.080	.200	.300	.600	.280	.130	.100	.060	.030	.030	.030	21
22	.130	.080	.190	.300	.660	.270	.120	.100	.060	.030	.030	.030	22
23	.130	.080	.180	.300	1.630	.270	.120	.100	.060	.030	.030	.030	23
24	.130	.150	.180	.300	.670	.260	.130	.100	.050	.030	.030	.030	24
25	.130	.150	.170	.300	.670	.250	.130	.100	.050	.030	.030	.030	25
26	.130	.150	.160	.300	.740	.250	.130	.100	.050	.030	.030	.030	26
27	.130	.150	.150	.300	.740	.240	.130	.090	.050	.030	.030	.030	27
28	.130	.150	.140	.300	.820	.230	.130	.090	.050	.030	.030	.030	28
29	.130	.150	.140	.300	0.000	.230	.130	.090	.050	.030	.030	.030	29
30	.130	.230	.130	.350	0.000	.230	.130	.090	.050	.030	.030	.030	30
31	.130	0.000	.130	.480	0.000	.230	0.000	.090	0.000	.030	.030	0.000	31
TOTAL	4.030	3.410	6.700	26.070	19.350	30.940	4.800	3.390	1.980	1.010	.930	.900	

TOTAL FOR WATER YEAR = 103.510 CUBIC METERS PER SECOND

= 13.72 MILLIMETERS

SIMULATED RUNOFF FOR SEIL ZERQA STREAMFLOW SIMULATION

WATER YEAR 1973

DAY	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	DAY
1	.086	.068	.216	.140	1.445	.594	.608	.376	.249	.176	.130	.099	1
2	.086	.069	.185	.139	.941	.620	.597	.371	.246	.175	.128	.098	2
3	.085	.125	.179	.138	.815	1.240	.587	.365	.243	.173	.127	.097	3
4	.084	.312	.186	.136	.775	2.859	.577	.360	.240	.171	.126	.096	4
5	.084	.124	.209	.135	.756	1.128	.567	.355	.237	.169	.125	.095	5
6	.083	.081	.166	.134	.740	2.114	.557	.350	.234	.167	.124	.095	6
7	.082	.070	.182	.133	.726	7.476	.549	.345	.231	.166	.123	.094	7
8	.082	.068	.179	.131	.712	5.140	.545	.340	.228	.164	.122	.093	8
9	.081	.067	.177	.130	.699	1.043	.559	.336	.226	.162	.120	.092	9
10	.080	.066	.175	.129	.686	1.167	.528	.331	.223	.161	.119	.092	10
11	.080	.066	.174	.128	.674	.941	.514	.327	.221	.159	.118	.091	11
12	.079	.065	.172	.169	.662	.897	.505	.322	.218	.157	.117	.090	12
13	.079	.065	.170	1.276	.650	.872	.496	.318	.215	.156	.116	.089	13
14	.078	.064	.168	6.444	.638	.852	.488	.313	.213	.154	.115	.089	14
15	.077	.064	.166	15.399	.627	.835	.481	.309	.211	.153	.114	.088	15
16	.077	.064	.165	25.842	.616	.819	.473	.305	.208	.151	.113	.087	16
17	.076	.063	.163	6.605	.605	.803	.465	.301	.206	.150	.112	.087	17
18	.076	.063	.161	2.642	.594	.788	.459	.297	.204	.148	.111	.086	18
19	.075	.062	.160	1.064	.584	.772	.451	.293	.201	.147	.110	.085	19
20	.075	.062	.159	.890	.574	.758	.444	.289	.199	.145	.109	.085	20
21	.074	.061	.157	.862	.564	.743	.437	.286	.197	.144	.108	.084	21
22	.074	.061	.155	.876	.667	.730	.430	.282	.195	.143	.107	.083	22
23	.073	.061	.153	.691	2.242	.717	.424	.278	.192	.141	.106	.083	23
24	.072	1.335	.152	.891	1.893	.703	.417	.275	.190	.140	.106	.082	24
25	.072	5.824	.150	.693	.905	.690	.411	.271	.188	.138	.105	.081	25
26	.071	1.404	.149	.873	.681	.677	.405	.268	.186	.137	.104	.081	26
27	.071	.419	.147	.861	.626	.665	.399	.265	.184	.136	.103	.080	27
28	.070	.215	.146	.845	.607	.653	.393	.261	.182	.135	.102	.080	28
29	.070	.211	.145	.829	0.000	.641	.387	.258	.180	.133	.101	.079	29
30	.069	.362	.143	.821	0.000	.630	.382	.255	.178	.132	.100	.078	30
31	.069	0.000	.142	.930	0.000	.619	0.000	.252	0.000	.131	.099	0.000	31
TOTAL	2.392	11.630	5.171	76.504	22.924	39.925	14.536	9.556	6.325	4.715	3.522	2.638	

TOTAL FOR WATER YEAR = 193.639 CUBIC METERS PER SECOND

= 25.69 MILLIMETERS

77/11/03

JORDAN CONTINUOUS DAILY STREAMFLOW SIMULATION MODEL

THE FOLLOWING ARE ANNUAL TOTALS IN MILLIMETERS

RAINFALL	=	190.18
MOISTURE IN DEPRESSION STORAGE	=	45.28
POTENTIAL EVAPORATION	=	2123.45
ESTIMATED ACTUAL EVAPORATION	=	154.23
EVAPORATION FROM DEPRESSION STORAGE	=	25.61
EVAPORATION FROM A HORIZON STORAGE	=	95.16
EVAPORATION FROM B HORIZON STORAGE	=	33.46
GROUNDWATER RECHARGE	=	14.39

RUNOFF FROM IMPERVIOUS AREAS	=	0.00
SURFACE RUNOFF	=	11.45
INTERFLOW THRU A HORIZON	=	0.00
BASE FLOW	=	14.24
LOSSES THRU SEEPS AND SPRINGS	=	11.53
TOTALL SIMULATED RUNOFF	=	25.69
TOTAL OBSERVED RUNOFF	=	13.72

STATISTICS	EXPA	EXPB	ERROR	SSERR	SSLOG	ABSV	OBFN	CCOF	SLOPE	YINT
	1.0000	0.0000	-6.0315	16.4079	94.4275	31.1014	31.1014	.7587	.5968	.0262

APPENDIX III

COMPUTER PROGRAMS LISTING

The first program is WTRAIN which computes the weighted daily rainfall over a basin. Subroutine PRINT lists daily rainfall for each station and it prints and punches on cards the computed weighted rainfall.

The Jordan watershed model consists of the main program, JORDSM, and seven subroutines. Subroutine MODEL performs streamflow simulation. Subroutine PANEVP utilizes pan evaporation measurements to compute estimated potential evapotranspiration. Parameters optimization is taking place in subroutine PAROPT. Subroutine PRINT lists tables of pan evaporation, rainfall, and observed and simulated streamflow. PLOTA and PLOTL are subroutines to plot streamflows on arithmatic and logarithmic scales respectively. Subroutine CPLOT is utilized to produce CALCOMP plotting of streamflows.

```
      PROGRAM WTRAIN(INPUT,OUTPUT,PUNCH,TAPE5=INPUT,TAPE6=OUTPUT,
     * TAPE7=PUNCH)
      DIMENSION SRF(10,367),STWT(10),RF(10,367)
C**   IPCH = 0 NO PUNCHED OUTPUT-CHECK RAINFALL DATA FOR EACH STATION.
C**   IPCH = 1 PUNCHED OUTPUT OF WEIGHTED DAILY RAINFALL.
      INTEGER BYEAR
      READ(5,100) NYEAR,BYEAR,IPCH
  100 FORMAT(4I4)
C**   NYEAR = NUMBER OF YEARS OF RECORD (MAXIMUM 10-YEARS)
C**   BYEAR = BEGINING YEAR OF RAINFALL RECORD.
C**   STWT(JST) = RAINFALL STATION WEIGHT.
C**   SRF(JST,I) = DAILY RAINFALL FOR STATION JST (MAXIMUM 10-STATIONS).
C**   RF(J,I) = WEIGHTED DAILY RAINFALL (MAXIMUM 10-YEARS).
      DO 25 J=1,10
      DO 25 I=1,367
      RF(J,I) = 0.0
   25 CONTINUE
      DO 40 JST=1,10
      STWT(JST) = 0.0
      DO 40 I=1,367
      SRF(JST,I) = 0.0
   40 CONTINUE
      DO 10 J=1,NYEAR
C**   NNYR = NUMBER OF DAYS IN A YEAR.
      NNYR = 365
      NYR = BYEAR+J-1
      IF(MOD(NYR,4) .EQ. 0) NNYR = 366
      JST = 0
C**   JST = PRESENT RAINFALL STATION.
      READ(5,125) NST,(STWT(I),I=1,NST)
  125 FORMAT(I4,3X,10F7.0)
C**   NST = NUMBER OF RAINFALL STATIONS.
   20 CONTINUE
      JST = JST + 1
      READ(5,120) (SRF(JST,I),I=1,NNYR)
  120 FORMAT(10F8.2)
      WRITE(6,1)
    1 FORMAT(1H1)
      WRITE(6,130) JST,NYR,STWT(JST)
  130 FORMAT(//16X,"DAILY RAINFALL STATION NUMBER",I2," FOR 19",I2,
     * " WATER YEAR",21X,"STATION WEIGHT =",F6.3///)
C**   CALL PRINT TO PRINT OUT STATIONS RAINFALL.
      CALL PRINT(NNYR,JST,SRF)
      DO 30 I =1,NNYR
      RF(J,I) = RF(J,I) + SRF(JST,I)*STWT(JST)
   30 CONTINUE
      IF(JST .EQ. NST) GO TO 15
      GO TO 20
   15 CONTINUE
      WRITE(6,1)
      WRITE(6,140)NYR
  140 FORMAT(//16X, "WEIGHTED DAILY RAINFALL FOR 19",I2," WATER YEAR"//)
C**   CALL PRINT TO PRINT OUT WEIGHTED RAINFALL.
      CALL PRINT (NNYR,J,RF)
      WRITE(6,1)
      IF(IPCH .EQ. 0) GO TO 11
C**   NOTE- THE FIRST CARD OF PUNCHED DECK IS 80 COL OF "*".
```

```
C**   THE SECOND CARD OF THE PUNCHED OUTPUT IS IDENTIFICATION CARD.    WTRAIN   58
      WRITE(7,122)                                                     WTRAIN   59
  122 FORMAT( 80("*"))                                                 WTRAIN   60
      WRITE(7,123)NYR                                                  WTRAIN   61
  123 FORMAT( 1X,"WEIGHTED DAILY RAINFALL FOR 19",I2," WATER YEAR")    WTRAIN   62
      WRITE(7,120) (RF(J,I) ,I=1,NNYR)                                 WTRAIN   63
   11 CONTINUE                                                         WTRAIN   64
   10 CONTINUE                                                         WTRAIN   65
      STOP                                                             WTRAIN   66
      END                                                              WTRAIN   67
```

```
      C**   SUBROUTINE TO PRINT OUT DAILY RAINFALL OF EACH STATION
      C**   AND WEIGHTED DAILY RAINFALL FOR A BASIN.
      C**
            SUBROUTINE PRINT(NNYR,J,RESULT)
      C**
            DIMENSION RESULT(10,367) , TOTAL(12)
            RESULT(J,367)=0.0
            ANNUAL=0.0
            DO 10 I=1,12
            TOTAL(I)=0.0
         10 CONTINUE
            L=0
            L11=0
            L2=0
            L4=0
            L6=0
            L9=0
            IF(NNYR.EQ.366)L=1
            WRITE(6,75)
         75 FORMAT("0",1X,"DAY",2X,"OCT.",6X,"NOV.",6X,"DEC.",6X,"JAN.",6X,"FE
           1B.",6X,"MAR.",6X,"APR.",7X,"MAY",6X,"JUNE",6X,"JULY",6X,"AUG.",6X,
           2"SEPT.",4X,"DAY"/)
            DO 60 N=1,31
            IF(N.GT.(28+L)) L2=244-N
            IF(N.LT.31) GO TO 20
            L11=305
            L4=154-L
            L6=93-L
            L9=1-L
         20 TOTAL(1)=TOTAL(1)+RESULT(J,N)
            TOTAL(2)=TOTAL(2)+RESULT(J,(31+N+L11))
            TOTAL(3)=TOTAL(3)+RESULT(J,(61+N))
            TOTAL(4)=TOTAL(4)+RESULT(J,(92+N))
            TOTAL(5)=TOTAL(5)+RESULT(J,(123+N+L2))
            TOTAL(6)=TOTAL(6)+RESULT(J,(151+N+L))
            TOTAL(7)=TOTAL(7)+RESULT(J,(182+N+L+L4))
            TOTAL(8)=TOTAL(8)+RESULT(J,(212+N+L))
            TOTAL(9)=TOTAL(9)+RESULT(J,(243+N+L+L6))
            TOTAL(10)=TOTAL(10)+RESULT(J,(273+N+L))
            TOTAL(11)=TOTAL(11)+RESULT(J,(304+N+L))
            TOTAL(12)=TOTAL(12)+RESULT(J,(335+N+L+L9))
      C**   PRINT DALILY RAINFALL FOR EACH MONTH.
            WRITE(6,65)N,RESULT(J,N),RESULT(J,(31+N+L11)),RESULT(J,(61+N)),RES
           1ULT(J,(92+N)),RESULT(J,(123+N+L2)),RESULT(J,(151+L+N)),RESULT(J,(1
           282+L+N+L4)),RESULT(J,(212+L+N)),RESULT(J,(243+L+N+L6)),RESULT(J,(2
           373+L+N)),RESULT(J,(304+L+N)),RESULT(J,(335+L+N+L9)),N
         65 FORMAT(I4,F8.3,11F10.3,I6)
         60 CONTINUE
            DO 30 M=1,12
         30 ANNUAL=ANNUAL+TOTAL(M)
            WRITE(6,40) (TOTAL(M),M=1,12) ,ANNUAL
         40 FORMAT(///1X,"TOTAL",F6.2,11F10.2///1X,"TOTAL FOR WATER YEAR = "
           1 ,F10.2," MILLIMETERS")
            RETURN
            END
```

```
      PROGRAM JORDSM(INPUT,OUTPUT,PUNCH,TAPE5=INPUT,TAPE6=OUTPUT,TAPE7
     1=PUNCH)
C**
C**
      INTEGER BYEAR,DAYS(2,12)
      DIMENSION TITLE(10),OBSY(5,367),PREDY(5,367)
      DIMENSION PLTR(2,31),LASTDA(2,12),RF(5,367),ET(5,367)
C**   DIMENION ET(J,I) AND PROVIDE BLOCK COMMON EVAP IN ORDER TO
C**   TRASFER NO OF DAYS IN A MONTH AND DAY NO IN A YEAR. JUNE 28,77
      REAL LOWERL
      DIMENSION PT(5,367)
      COMMON/EVAP/ LASTDA,DAYS,EPAR,NEVP
      COMMON/SEA/ SQKM,ET,PT
      COMMON/RAIN/ADATE,RF,OBSY,PREDY
      COMMON/SYN/ NYRS,BYEAR,II,NSET
      COMMON/MP/DP(12,31)
      COMMON/OPTM/ IOPT,OPPAR(10),PRPAR(10),DELTA(10),LOWERL(10),
     *UPPERL(10),OBFN,NPAR,NSTART,NDLTA,MXRES,MXRUN,EXPA,EXPB,BETA(10)
     *,IROP
C**   LASTD(2,12) = NO OF DAYS IN EACH MONTH OF A LEAP AND A REGULAR
C**   YEARS RESPECTIVILY BEGINING WITH JANUARY.
      DATA LASTDA/31,31,29,28,31,31,30,30,31,31,30,30,31,31,31,31,30,30,
     131,31,30,30,31,31/
C**   DAYS(2,12) = DAY NUMBER IN EACH PREVIOUS MONTH OF A LEAP AND A
C**   NON-LEAP YEAR RESPECTIVILY BEGINING WITH JANUARY.
      DATA DAYS/92,92,123,123,152,151,183,182,213,212,244,243,274,273,
     1305,304,336,335,0,0,31,31,61,61/
      CALL DATE(ADATE)
      READ(5,5) NSHED
C**   BEGIN WATERSHED LOOP.
      DO 100 NNNN=1,NSHED
      DO 1 J=1,5
      DO 1 M=1,367
C**   ZERO OUT ET(J,M) DAILY PAN EVAO. MEASUREMENTS. JUNE 28,77
      ET(J,M) = 0.0
      PT(J,M) = 0.0
      OBSY(J,M)=0.0
      PREDY(J,M)=0.0
      RF(J,M)=0.0
    1 CONTINUE
C**
C**   INPUT DATA IN MAIN PROGRAM.
C**
      READ(5,2)TITLE
    2 FORMAT(10A8)
      READ(5,5)  NOBSY,NEVP,IOPT,IROP  ,IPLOT,IPLOTL,ICPLOT,LOGS,NCARD
      READ(5,10) EXPA,EXPB
    5 FORMAT(10I4)
      IF(NCARD.EQ.1) READ(5,3) TITE
    3 FORMAT(A2)
      WRITE(6,4)
    4 FORMAT("1")
C**
      IF(IOPT .EQ. 0) GO TO 12
      READ(5,5) NPAR,MXRES,MXRUN,NDLTA
      READ(5,10) (PRPAR(I),I=1,NPAR)
      READ(5,10) (UPPERL(I),I=1,NPAR)
```

```
      READ(5,10) (LOWERL(I),I=1,NPAR)
      READ(5,10) (DELTA(I) ,I=1,NPAR)
   10 FORMAT(10F8.0)
   12 CONTINUE
C**
C**
      ISTART = 1
C**   ISTART = 1 CALL MODEL TO READ DATA FOR THE FIRST SET OF 5-YEARS
C**
      CALL MODEL(OBSY,TITLE,ISTART,NOBSY)
C**   OBSY ARE IN CUBIC METERS PER SECOND. MAY 23,77
C     THE PROGRAM WORKS IN SET OF 5 YEARS AT A TIME FOR DIMENSION REASON
C     NSET = THE NUMBER OF SET OF 5 YEARS OF DATA.  COMPUTED IN PROGRAM
C**   BEGIN SIMULATION LOOP FOR EACH SET OF 5-YEARS
C**
      DO 20 II=1,NSET
C**   ISTART = 3 CALL MODEL TO READ DATA FOR THE NEXT SET OF 5-YEAR
C**
      IF(II .GT. 1) CALL MODEL(OBSY,TITLE,3,NOBSY)
      DO 15 J=1,5
      DO 15 M=1,367
      PREDY(J,M)=OBSY(J,M)
   15 CONTINUE
      ISTART=2
      IF(II.GT.1) ISTART=4
C**   ISTART = 2 CALL MODEL TO SIMULATE THE FIRST SET OF 5-YEARS
C**
C**
C**   ISTART = 4 CALL MODEL TO SIMULATE THE NEXT SET OF 5-YEARS
C**
      CALL MODEL(PREDY,TITLE,ISTART,NOBSY)
C**   PREDY ARE IN CUBIC METERS PER SECOND. MAY 23,77
      DO 30 J=1,NYRS
C**
      NNYR=365
      IF(MOD((BYEAR+J-1),4).EQ.0) NNYR=366
      NYEAR=BYEAR+J-1
C**
      IF(NOBSY .EQ. 0) GO TO 50
      IF(IPLOT .EQ. 0) GO TO 50
      WRITE(6,17)ADATE
   17 FORMAT("1",A9,21X,"JORDAN CONTINUOUS DAILY STREAMFLOW SIMULATION M
     1ODEL"//)
   50 CONTINUE
      IF(NCARD.NE.1) GO TO 60
C**
C**   PUNCH OUT THE SIMULATED FLOWS ON CARDS IN CU METERS PER SECOND.
      IEND=0
      IBEG = 1
      NNNYR = 8
      DO 43 M =1,40
      IEND=IBEG+NNNYR-1
      WRITE(7,400) (PREDY(J,MM),MM=IBEG,IEND),TITE,NYEAR,M
  400 FORMAT(9F8.3,1X,A2,I2,1X,I2)
   43 CONTINUE
      IEND=NNYR
      IF(NNYR.EQ.365) IEND=366
```

```
      WRITE(7,450) (PREDY(J,MM),MM=361,IEND),TITE,NYEAR
  450 FORMAT(6F8.3,25X,A2,I2,1X,"41")
   60 IF(NOBSY.EQ.0) GO TO 42
      IF( IPLOT .EQ. 0) GO TO 40
      WRITE(6,46) TITLE,NYEAR
   46 FORMAT(" SIMULATED RUNOFF FOR ",10A8,"WATER YEAR 19",I2//)
      CALL PLOTA(OBSY,PREDY,RF,NNYR,J,6)
   40 CONTINUE
C**
C**   ADD LOG SCALE PLOTTING ROUTINE "PLOTL"  DATE FEB. 18 ,77
      ISIZE = 1
      IF(SQKM .LT. 1000.0) ISIZE = 0
C**   CONVERT TO METRIC SYSTEM-CHANGE FORMAT AND PLOTTING LABLES
C**   DATE: MARCH 3,77
      IF(IPLOTL .EQ. 0) GO TO 25
      WRITE(6,140) ADATE,TITLE,NYEAR
  140 FORMAT("1",A9,5X,"MEAN DAILY STREAMFLOW FOR",10A8,"WATER YEAR 19",
     1I2//22X,"DISCHARGE IN CUBIC METERS PER SECOND(S=SIMULATED,O=OBSERV
     2ED)")
      IF(ISIZE .EQ. 0) WRITE(6,141)
  141 FORMAT(127X,"RAIN"/123X,"(MILLIMETERS)"//4X,"0.01",26X,"0.10",26X,
     *"1.00",25X,"10.00",24X,"100.00"/5X,"-",12("----------"))
      IF(ISIZE .EQ. 1) WRITE(6,142)
  142 FORMAT(127X,"RAIN"/123X,"(MILLIMETERS)"//4X,"0.10",26X,"1.00",25X,
     *"10.00",24X,"100.00",23X,"1000.00"/5X,"-",12("----------"))
   25 CONTINUE
      DO 41 M=1,12
      MM=M+9
      IF(MM.GT.12)MM=MM-12
      ILY=2
      IF(MOD(NYEAR,4).EQ.0)ILY=1
      LD=LASTDA(ILY,MM)
      DO 45 JJ=1,LD
      JK=DAYS(ILY,MM)+JJ
      DP(MM,JJ)=RF(J,JK)
C**   OBSERVED AND PREDICTED FLOWS ARE IN CU METERS PER SEC. MAY 23,77
      PLTR(1,JJ)= OBSY(J,JK)
   45 PLTR(2,JJ) = PREDY(J,JK)
   41 CALL PLOTL(LD,PLTR,MM,ISIZE,IPLOTL)
      IF( IPLOTL .EQ. 0) GO TO 42
      WRITE(6,44)
   44 FORMAT(5X,"-",12("----------"))
   42 WRITE(6,17)
      WRITE(6,46) TITLE,NYEAR
C**   CALL PRINT TO LIST SIMULATED FLOWS IN CUBIC METERS PER SECOND
      CALL PRINT(NNYR,J,PREDY,2)
C**   CALL CPLOT FOR CALCOMP PLOTTING IF ICPLOT =1
      IF(ICPLOT .EQ. 1) CALL CPLOT(NYRS,NNYR,J,OBSY,PREDY,LOGS)
   30 CONTINUE
   20 CONTINUE
  100 CONTINUE
      STOP
      END
```

```
C**
C**   SUBROUTINE MODEL FOR SIMULATING DAILY FLOWS AND PARAMETERS
C**   OPTIMIZATION AND SIMULATION USING THE BEST VALUES OF PARAMETER SET
C**
C**
C**
      SUBROUTINE MODEL(QDAY,TITLE,ISTART,NOBSY)
      INTEGER BYEAR
      REAL LOWERL
      DIMENSION FPAR(10),BPAR(10),PT(5,367)
      DIMENSION ET(5,367),RF(5,367),QDAY(5,367)
     *,TITLE(10),TOTALW(20),LDAY(2,12),NDAY(2,12),TMW(20),OBMM(5,367)
      COMMON/EVAP/ LDAY,NDAY,EPAR,NEVP
      COMMON/SEA/ SQKM,ET,PT
      COMMON/SYN/ NYRS,BYEAR,NN,NSET
      COMMON/OPTM/ IOPT,OPPAR(10),PRPAR(10),DELTA(10),LOWERL(10),
     *UPPERL(10),OBFN,NPAR,NSTART,NDLTA,MXRES,MXRUN,EXPA,EXPB,BETA(10)
     *,IROP
      COMMON/RAIN/ADATE,RF
      REAL IFVOL,IFRES,IFRO
C**
C**   ISTART = 1 READ INPUT DATA FOR THE FIRST SET OF 5-YEARS
C**   ISTART = 2 BEGIN SIMULATION FOR THE FIRST SET OF 5-YEARS
C**   ISTART = 3 READ INPUT DATA FOR THE NEXT SET OF 5-YEARS
C**   ISTART = 4 BEGIN SIMULATION FOR THE NEXT SET OF 5-YEARS
C**
      IF(ISTART.EQ.4) GO TO 63
      IF(ISTART.EQ.3) GO TO 12
      IF(ISTART.NE.1)GO TO 49
C**   IOPT = 0  NO PARAMETERS OPTIMIZATION.
C**   IOPT = 1  PARAMETERS OPTIMIZATION.
      IF(IOPT .EQ. 1) GO TO 2
C**   READ MODEL PARAMETERS IF OPTIMIZATION IS NOT DESIRED.
      READ(5,4) FMAX,FMIN,ALFN,AHORD,BHORP,FSRO,REXP,BHORD,EPAR,DLOSS,
     *BSMI,BCWR,WCEPT,SQKM,FROK,SGWK,PGWK,SROK,PIMP,TRLOS
    4 FORMAT(10F8.0)
      GO TO 6
    2 CONTINUE
      LPAR= 20 - NPAR
C**   READ VALUES OF THE FIXED PARAMETERS(NOT TO BE OPTIMIZED).
      READ(5,4) (FPAR(I),I=1,LPAR)
      BSMI =  FPAR(1)
      BCWR =  FPAR(2)
      WCEPT=  FPAR(3)
      SQKM =  FPAR(4)
      FROK =  FPAR(5)
      SGWK =  FPAR(6)
      PGWK =  FPAR(7)
      SROK =  FPAR(8)
      PIMP =  FPAR(9)
      TRLOS=  FPAR(10)
C**   BPAR(KK) = INITIAL VALUES OF OPTIMIZED PARAMERTERS PRPAR(KK).
      DO 14 KK =1,NPAR
      BPAR(KK) = PRPAR(KK)
   14 CONTINUE
    6 CONTINUE
C**
```

```
      C**   READ NO OF YEARS AND BEGINING WATER YEAR OF SIMULATION.
      C**
            READ(5,7) NYRS,BYEAR
          7 FORMAT(2I4)
      C**
            LYEAR=BYEAR+NYRS-1
            IF(IOPT .EQ. 1) GO TO 8
            WRITE(6,17)ADATE
         17 FORMAT(  1X,A9,21X,"JORDAN CONTINUOUS DAILY STREAMFLOW SIMULATION
           1MODEL"//)
            WRITE(6,40) TITLE,BYEAR,LYEAR
         40 FORMAT(31X,10A8////////10X,"FOLLOWING ARE PARAMETERS AND CONSTANTS
           1FOR YEAR(S) 19",I2,"-19",I2//)
            WRITE(6,800)BSMI,BGWR,FMAX,FMIN,AHORD,BHORP,BHORD,REXP,WCEPT,SQKM
        800 FORMAT( 13X,"BSMI",4X,"BGWR",4X,"FMAX",4X,"FMIN",4X,"AHORD",3X,
           *"BHORP",3X,"BHORD",3X,"REXP",4X,"WCEPT",3X,"SQKM",/10X,10F8.2/)
            WRITE(6,810) EPAR,FSRO,SROK,FROK,SGWK,PGWK,ALFN,DLOSS,PIMP,TRLOS
        810 FORMAT( 13X,"EPAR",4X,"FSRO",4X,"SROK",4X,"FROK",4X,"SGWK",4X,
           *"PGWK",4X,"ALFN",3X,"DLOSS",3X,"PIMP",4X,"TRLOS",/9X,6F8.3,1X,
           *4F8.3)
          8 CONTINUE
            NSTART = 0
            NN=1
            NSET=NYRS/5
            NR=NYRS-5*NSET
            IF(NR.NE.0) NSET=NSET+1
         12 NYRS=5
            IF(NN.EQ.NSET.AND.NR.NE.0) NYRS=NR
            IF(NN.GT.1) BYEAR=BYEAR+5
      C**
      C**   BEGIN YEAR LOOP OF READING PAN EVP,RAINFALL AND STREAMFLOW DATA
      C**
            DO 10 J=1,NYRS
      C**
            NYR = BYEAR+J-1
            NNYR=365
      C**
            IF(MOD(NYR,4) .EQ. 0) NNYR = 366
            WRITE(6,600)
            WRITE(6,17) ADATE
      C**   CALL PANEVP TO READ AND PRINT PAN EVAPORATION. MAY 26,77
            CALL PANEVP(J,TITLE,NYR)
            WRITE(6,600)
        600 FORMAT("1")
            WRITE(6,17) ADATE
      C**
      C**   READ DAILY RAINFALL DATA FOR THE FIRST YEAR
      C**
            READ(5,5) (RF(J,I),I=1,NNYR)
          5 FORMAT( 10F8.0)
            WRITE(6,1) NYR,TITLE
          1 FORMAT(" RAINFALL FOR YEAR 19",I2,10X,10A8,"VALUES IN MILLIMETERS"
           1)
      C**   PRINT DAILY RAINFALL OF THE PRESENT YEAR.
            CALL PRINT(NNYR,J,RF,1)
            DO 20 I=1,NNYR
            OBMM(J,I) = 0.0
```

```
   20 CONTINUE
      IF(NOBSY .EQ. 0) GO TO 10
C**
C**   READ DAILY STREAMFLOW DATA FOR THE FIRST YEAR
C**
      READ(5,5)(QDAY(J,I),I=1,NNYR)
      DO 30 I=1,NNYR
C**   CONVERT OBSERVED FLOWS TO MILLIMETERS AND SAVE THESE VALUES(OBMMD
C**   FOR THE PURPOSE OF PERFORMING STATISTICS.
      OBMM(J,I) = QDAY(J,I)*86.4/SQKM
   30 CONTINUE
      WRITE(6,600)
      WRITE(6,17) ADATE
      WRITE(6,9) NYR,(TITLE(I),I=1,7)
    9 FORMAT(2X,"OBSERVED RUNOFF FOR YEAR 19",I2,6X, 7A8,"VALUES IN CUBI
     1C METERS PER SECOND")
C**   PRINT OBSERVED FLOWS IN CUBIC METERS PER SECOND. MAY 23,1977
      CALL PRINT(NNYR,J,QDAY,2)
C**   OBSERVED FLOWS QDAY ARE SO FAR IN CUBIC METERS PER SEC. MAY,23,77
   10 CONTINUE
      IF(IOPT .NE. 1) GO TO 500
      WRITE(6,600)
      WRITE(6,94) (FPAR(K) ,K=1,LPAR)
   94 FORMAT(   //5X,"THE FOLLOWING IS THE FIXED AND INITIAL PARAMETER V
     *ALUES"///5X,"PARAMETER"11X,"BSMI",5X,"BGWR",5X,"WCEPT",5X,
     *"SQKM",5X,"FROK",5X,"SGWK",5X,"PGWK",5X,"SROK" ,5X,"PIMP",5X,
     *"TRLOS"//5X,"FIXED VALUE",5X,10F9.3//)
      WRITE(6,96)(PRPAR(K),K=1,NPAR),(UPPERL(K1),K1=1,NPAR),
     * (LOWERL(K2),K2=1,NPAR), (DELTA(K3),K3=1,NPAR)
   96 FORMAT(   /5X,"PARAMETER",10X,"FMAX",5X,"FMIN",5X,"ALFN",5X,
     *"AHORD",5X,"BHORP",5X,"FSRO",5X,"REXP",5X,"BHORD",5X,"EPAR",5X,
     *"DLOSS"//5X,"INITIAL VALUE",3X,10F9.3/
     *5X,"UPPER LIMIT",5X,10F9.3/
     *5X,"LOWER LIMIT",5X,10F9.3/
     *5X,"INCREMENT",7X,10F9.3//)
      NEND = 0
      GO TO 500
C**
C**   BEGIN SIMULATION OF THE FIRST SET OF 5-YEARS
C**
   49 CONTINUE
      IF(IOPT .EQ. 0) GO TO 50
C**   THE FOLLOWING PARAMETERS ARE THE PARAMETERS TO BE OPTIMIZED.
      FMAX = PRPAR(1)
      FMIN = PRPAR(2)
      ALFN = PRPAR(3)
      AHORD= PRPAR(4)
      BHORP= PRPAR(5)
      FSRO = PRPAR(6)
      REXP = PRPAR(7)
      BHORD= PRPAR(8)
      EPAR = PRPAR(9)
      DLOSS= PRPAR(10)
   50 CONTINUE
C**
C**   INIALIZE RESERVOIR STORAGES AND INIAL SOIL MOISTURE AND GW STORAGE
      SURO = 0.0
```

```
      IFREC = 0.0                                                       MODEL     172
      SURES=0.0                                                         MODEL     173
      AHOR=0.0                                                          MODEL     174
      BHOR = BSMI                                                       MODEL     175
      PGWR = BGWR                                                       MODEL     176
      CNIF = (FMAX-FMIN)/(1.0-EXP(-ALFN*AHORD))                         MODEL     177
C**   GWRM-MIN. GWR..GWRX-MAX. GWR,ALGW-DECAY EXP OF BASE FLOW REC FUN. MODEL     178
      GWRM = BGWR                                                       MODEL     179
      GWRX = 50.0                                                       MODEL     180
      ALGW = 0.05                                                       MODEL     181
      EXPON = 1.0 - EXP(-ALGW*(GWRX-GWRM))                              MODEL     182
      FACTOR = (PGWK-SGWK)/EXPON                                        MODEL     183
C**   COMPUTE RECESSION FACTOR "K"FOR THE FIRST DAY.                    MODEL     184
C**   PGWK-PRIMARY(SUMMER) RECESSION FACTOR.                            MODEL     185
C**   SGWK/SECONDARY(WINTER) RECESSION FACTOR.                          MODEL     186
      GWRK = (PGWK-FACTOR) + FACTOR*EXP(-ALGW*(PGWR-GWRM))              MODEL     187
      IF(GWRK .GT. 0.999) GWRK = 0.999                                  MODEL     188
      IF(GWRK .LT. SGWK) GWRK = SGWK                                    MODEL     189
C**   COMPUTE BASE FLOW FOR THE FIRST DAY.                              MODEL     190
      PGRO = PGWR*(1.0-GWRK)                                            MODEL     191
  610 FORMAT(32X,"DAILY MOISTURE ALLOCATION (VALUES IN MILLIMETERS)"///)MODEL     192
   45 FORMAT(1X,"YEAR",1X,"MO",1X,"DAY",1X,"RAIN",1X,"PET",3X,"AET",2X, MODEL     193
     *"PSRO",2X,"SURVOL",1X,"SURES",3X,"SURO",2X,"IFVOL",2X,"IFRES",3X, MODEL     194
     *"IFRO",3X,"INEL",1X,"DRAIN",1X,"RECHAR",1X,"DLOSS",4X,"PGWR",2X,  MODEL     195
     *"GWRK",4X,"GWRO",2X,"AHOR",2X,"BHOR"/)                            MODEL     196
C**   DELETE THREE MONTH LEAD IN PERIOD SIMULATION ROUTINE              MODEL     197
C**   NO RAINFALL DURING THIS PERIOD .DATE MARCH 22,77                  MODEL     198
C**   BEGIN SIMULATING BY YEARS                                         MODEL     199
   63 CONTINUE                                                          MODEL     200
C**                                                                     MODEL     201
C**   BEGIN YEAR LOOP OF SIMULATION                                     MODEL     202
C**                                                                     MODEL     203
      DO 65 J=1,NYRS                                                    MODEL     204
      DO 15 I=1,20                                                      MODEL     205
      TMW(I) = 0.0                                                      MODEL     206
      TOTALW(I) = 0.0                                                   MODEL     207
   15 CONTINUE                                                          MODEL     208
      NYR = BYEAR+J-1                                                   MODEL     209
      NYRW = NYR                                                        MODEL     210
      NNYR=365                                                          MODEL     211
C**                                                                     MODEL     212
      IF(MOD(NYR,4) .EQ. 0) NNYR = 366                                  MODEL     213
      ID = 2                                                            MODEL     214
      IF(NNYR .EQ. 366) ID = 1                                          MODEL     215
C**                                                                     MODEL     216
C**   CALL POTEVP TO COMPUTE ET FROM PAN EVAPORATION.                   MODEL     217
      CALL POTEVP(J,TITLE,NYR)                                          MODEL     218
      M = 10                                                            MODEL     219
C**                                                                     MODEL     220
      IF(IOPT .EQ. 1) GO TO 46                                          MODEL     221
      WRITE(6,600)                                                      MODEL     222
      WRITE(6,17) ADATE                                                 MODEL     223
      WRITE(6,610)                                                      MODEL     224
      WRITE(6,45)                                                       MODEL     225
   46 CONTINUE                                                          MODEL     226
C**                                                                     MODEL     227
C**   BEGIN DAILY LOOP OF SIMULATION                                    MODEL     228
```

```
C**
      DO 100 I=1,NNYR
      NYR = NYRW
C**   CONVERT SEQUANTIAL DAYS TO DAYS IN EACH MONTH.
      N = I - NDAY(ID,MD)
      IF(N .LE. LDAY(ID,MD)) GO TO 70
      M = M + 1
      IF(M .GT. 12) M = M-12
   70 CONTINUE
      N = I - NDAY(ID,MD)
      IF(M .GE. 10) NYR = NYRW - 1
C**   ALEB AND ETAP ARE EXPONONTS OF EVP FUNCTIONS OF A&B HORIZONS.
      ALEB = 0.060
      ETAP = 0.075
      DRXP = 2.00
C**   INITIALIZE VARIOUS VARIABLES.
      REINC = 0.0
      RECHA = 0.0
      DRAIN = 0.0
      GWLOS = 0.0
      IFVOL = 0.0
      IFRO = 0.0
      TORO = 0.0
      TSRO = 0.0
      ETI = 0.0
      ETA = 0.0
      ETB = 0.0
      PINF = 0.0
      AINF = 0.0
      AET = 0.0
      PSRO = 0.0
      TCEPT = 0.0
      EMFR = 0.0
      EMFI = 0.0
      EMFU = 0.0
      EMTA = 0.0
      EMTB = 0.0
      EMTR = 0.0
      SURVOL = 0.0
      SURLOS = 0.0
      TORO = OBMH(J,I)
      EMFR = RF(J,I)
C**   PET=POTENTIAL EVAPORATION FROM ALL STORAGE COMPARTMENTS
C**   AS CALCULATED IN PANEVP SUBROUTINE. JUNE 28,77
      PET = PT(J,I)
      ETD = PET
      IF(EMFR .EQ. 0.0) GO TO 80
      IF(EMFR .GT. WCEPT) GO TO 71
C**   ALLOCATE MOISTURE TO DEPRESSION STORAGE.
      TCEPT = EMFR - EMFR*EMFR/(2.0*WCEPT)
      GO TO 78
   71 CONTINUE
      TCEPT = WCEPT/2.0
   78 CONTINUE
      EMFI = EMFR - TCEPT
      TOTALW(2) = TOTALW(2) + TCEPT
      TMW(2) = TMW(2) + TCEPT
```

```
      IF(TCEPT .GT. PET) GO TO 76
C**   DEPLETE DEPRESSION STORAGE DUE TO EVAPORATION DEMAND
      ETI = TCEPT
      AET = AET + TCEPT
      ETD = PET - TCEPT
      TCEPT = 0.0
      GO TO 79
C**   SATISFY EVAP DEMAND FROM DEPRESSION STORAGE
C**   AND MOVE EXCESS MOISTURE TO UPPER SOIL MOISTURE STORAGE
   76 TCEPT = TCEPT - PET
      ETI = PET
      AET = AET + PET
      ETD = 0.0
C**
   79 CONTINUE
C**   COMPUTE RUNOFF FROM IMPERVIOUS AREAS.
      PSRO = EMFI*PIMP
      EMFU = EMFI - PSRO
C**   COMPUTE TRANSMISSION LOSSES FROM IMP. AREA RUNOFF.
      ENTR = PSRO*TRLOS
      PSRO = PSRO*(1.0-TRLOS)
      EMTA = EMFU + EMTR
   80 CONTINUE
      EMTA = EMTA + TCEPT
C**   COMPUTE EVAP FROM A HORIZON DEPENDING ON MOISTURE STORAGE. JUNE 28
      TETA = ETD*(AHOR/AHORD)**ETAP
C**   CHECK IF AVAILABLE MOISTURE SATISTIES EVAP. JUNE 28,77
      IF(AHOR .LE. TETA) GO TO 86
C**   REMOVE ALL EVAP DEMAND FROM A HORIZON. JUNE 28,77
      AHOR = AHOR - TETA
      ETA = TETA
      AET = AET + TETA
C**   COMPUTE EVAPORATION DEMAND FROM LOWER SOIL MOISTURE STORAGE.
      ETD = ETD - TETA
      GO TO 90
   86 CONTINUE
      ETD = ETD - AHOR
      ETA = AHOR
      AET = AET + AHOR
C**   A HORIZON IS DEPLETED. JUNE 28,77
      AHOR = 0.0
   90 CONTINUE
C**
C**   COMPUTE EVAP FROM B HORIZON AT A REDUCED RATE TO ACCOUNT
C**   FOR THE DRYNESS OF UPPER A HORIZON.
      TETB = EPAB*ETD*EXP(-ALEB*(BHORD-BHOR))
   91 CONTINUE
C**   REMOVE EVAP FROM B HORIZON. JUNE 28,77
      IF(BHOR .LE. TETB) GO TO 66
      BHOR = BHOR -TETB
      ETB = TETB
      AET = AET + TETB
      GO TO 67
C**
   66 ETB = BHOR
      AET = AET + BHOR
      ETD = 0.0
```

```
      BHOR = 0.0
   67 CONTINUE
C**   COMPUTE POINT INFILTRATION TO A HORIZON STORAGE.
      PINF = (FMAX-CNIF) + CNIF*EXP(-ALFN*AHOR)
      IF(PINF .LT. FMIN) PINF = FMIN
      IF(EMTA .GT. PINF) GO TO 72
C**   COMPUTE AVERAGE INFILTRATION AND SURFACE RUNOFF VOLUME.
      AINF = EMTA - EMTA*EMTA/(2.0*PINF)
      SURVOL = EMTA - AINF
      AHOR = AHOR + AINF
      IF(AINF .LT. 0.0001) AINF = 0.0
      GO TO 73
   72 CONTINUE
      AINF = PINF/2.0
      SURVOL = EMTA - AINF
      IF(SURVOL .LT. 0.0001) SURVOL = 0.0
      AHOR = AHOR + AINF
   73 CONTINUE
C**   COMPUTE INTERFLOW VOLUME WHEN AHOR EXCEEDS ITS CAPACITY.
      IFVOL = AHOR - AHORD
      IF(IFVOL .LT. 0.0) GO TO 75
      IF(IFVOL .LT. 0.0001) IFVOL = 0.0
      AHOR = AHORD
      IFRES = IFRES + IFVOL
      GO TO 81
   75 CONTINUE
      IFVOL = 0.0
   81 CONTINUE
      IFRO = (1.0-FROK)*IFRES
      IFRES = IFRES - IFRO
      IF(IFRES.LT. 0.0001) IFRES = 0.0
      IF(IFRO .LT. 0.0001) IFRO = 0.0
C**   COMPUTE DRAINAGE FROM A HORIZON TO B HORIZON.
      DRAIN = BHORP*(1.0-((BHOR/BHORD)**2.00))*(AHOR/AHORD)**DRXP
      IF(DRAIN .LT. 0.0001) DRAIN = 0.0
      IF(AHOR .LT. DRAIN) DRAIN = AHOR
      AHOR = AHOR - DRAIN
C**   COMPUTE G.W. RECHARGE FROM B HORIZON TO GW RESERVOIR STORAGE.
      RECHA = DRAIN*(BHOR/BHORD)**REXP
      BHOR = BHOR + DRAIN - RECHA
      REINC = 0.0
      IF(BHOR .GT. BHORD) REINC = BHOR - BHORD
C**
C**
      BHOR = BHOR - REINC
      IF(RECHA .LT. 0.0001) RECHA = 0.0
   95 CONTINUE
C**
C**   ROUTE GROUND WATER RUNOFF FOR EACH DAY.
C**   COMPUTE G.W. LOSSES AND NET G.W. RECHARGE.
      GWLOS = DLOSS*RECHA
      RECHA = RECHA - GWLOS
      PGWR = PGWR + RECHA
C**   COMPUTE BASE FLOW RECESSION CONSTANT.
      GWRK = (PGWK-FACTOR) + FACTOR*EXP(-ALGW*(PGWR-GWRM))
      IF(GWRK .GT. 0.999) GWRK = 0.999
      IF(GWRK .LT. SGWK) GWRK = SGWK
```

```
      PGRO = PGWR*(1.0-GWRK)
      PGWR = PGWR - PGRO                                                MODEL 400
      AHOR = AHOR + REINC                                               MODEL 401
C**   COMPUTE SURFACE RUNOFF SRO WHICH CONSISTS OF THE FOLLOWING        MODEL 402
C**      1.  ROUTED SURVOL (FSRO*SURVOL).                               MODEL 403
C**      2.  MOISTURE DEPLETED FROM SURFACE R.O STORAGE SURES*(1-SROK)  MODEL 404
      SURO = FSRO*SURVOL + SURES*(1.0-SROK)                             MODEL 405
C**   PERFORME MOISTURE ACCOUNTING OF SURFACE RUNOFF STORAGE            MODEL 406
C**      MOISTURE GOING TO  STORAGE SURVOL*(1-FSRO).                    MODEL 407
C**      MOISTURE LEAVING STORAGE  SURES*(1-SROK).                      MODEL 408
      SURES = SURES + SURVOL*(1.0-FSRO) - SURES*(1.0-SROK)              MODEL 409
      IF(SURES .LE. 0.0001) SURES = 0.0                                 MODEL 410
C**                                                                     MODEL 411
C**   TOTAL DAILY FLOW IS EQUAL TO ALL COMPUTED RUNOFF COMPONENTS.      MODEL 412
      QDAY(J,I) = PSRO + SURO + IFRO + PGRO                             MODEL 413
      TSRO = QDAY(J,I)                                                  MODEL 414
C**   CONVER SIMULATED STREAMFLOWS FROM MILLIMETERS TO CU. M/SEC.8/23/77MODEL 415
      QDAY(J,I) = QDAY(J,I)*SQKM/86.4                                   MODEL 416
      IF(QDAY(J,I).LT.0.0001) QDAY(J,I)=0.0                             MODEL 417
      IF(IOPT .EQ. 1) GO TO 85                                          MODEL 418
      WRITE(6,88) NYR,M,N,RF(J,I),PET,AET,PSRO,SURVOL,SURES,SURO,IFVOL, MODEL 419
     *IFRES,IFRO,AINF,DRAIN,RECHA,GWLOS,PGWR,GWRK,PGRO,AHOR,BHOR         MODEL 420
   88 FORMAT(1X,"19",I2,2I3,F6.2,2F5.2,7F7.4,2F6.2,2F7.4,1X,F7.4,F6.4,  MODEL 421
     * F7.4,F6.2,F7.2)                                                  MODEL 422
C**   ANNUAL MOISTURE SUMMARY.                                          MODEL 423
   99 TOTALW(1) = TOTALW(1) + EMFR                                      MODEL 424
      TOTALW(3) = TOTALW(3) + PET                                       MODEL 425
      TOTALW(4) = TOTALW(4) + AET                                       MODEL 426
      TOTALW(5) = TOTALW(5) + ETI                                       MODEL 427
      TOTALW(6) = TOTALW(6) + ETA                                       MODEL 428
      TOTALW(7) = TOTALW(7) + ETB                                       MODEL 429
      TOTALW(8) = TOTALW(8) + PSRO                                      MODEL 430
      TOTALW(9) = TOTALW(9) + SURO                                      MODEL 431
      TOTALW(10) = TOTALW(10) + IFRO                                    MODEL 432
      TOTALW(11) = TOTALW(11) + PGRO                                    MODEL 433
      TOTALW(12) = TOTALW(12) + GWLOS                                   MODEL 434
      TOTALW(13) = TOTALW(13) + TSRO                                    MODEL 435
      TOTALW(14) = TOTALW(14) + TORO                                    MODEL 436
      TOTALW(15) = TOTALW(15) + RECHA                                   MODEL 437
C**   MONTHLY MOISTYRE SUMMARY.                                         MODEL 438
      TMW(1) = TMW(1) + EMFR                                            MODEL 439
      TMW(3) = TMW(3) + PET                                             MODEL 440
      TMW(4) = TMW(4) + AET                                             MODEL 441
      TMW(5) = TMW(5) + ETI                                             MODEL 442
      TMW(6) = TMW(6) + ETA                                             MODEL 443
      TMW(7) = TMW(7) + ETB                                             MODEL 444
      TMW(8) = TMW(8) + PSRO                                            MODEL 445
      TMW(9) = TMW(9) + SURO                                            MODEL 446
      TMW(10) = TMW(10) + IFRO                                          MODEL 447
      TMW(11) = TMW(11) + PGRO                                          MODEL 448
      TMW(12) = TMW(12) + GWLOS                                         MODEL 449
      TMW(13) = TMW(13) + TSRO                                          MODEL 450
      TMW(14) = TMW(14) + TORO                                          MODEL 451
      TMW(15) = TMW(15) + RECHA                                         MODEL 452
      IF(N .NE. LDAY(ID,MD) GO TO 85                                    MODEL 453
      WRITE(6,489)                                                      MODEL 454
  489 FORMAT(//1X,"THE FOLLOWING ARE MONTHLY TOTALS IN MILLIMETERS"//)  MODEL 455
                                                                        MODEL 456
```

```
      WRITE(6,490) (TMW(K),TMW(K+7),K=1,7),TMW(15)
  490 FORMAT(8X,"RAINFALL",30X,"= ",F7.2,28X,
     *"RUNOFF FROM IMPERVIOUS AREAS = ",F7.2//
     *8X,"MOISTURE IN DEPRESSION STORAGE",8X,"= ",F7.2,28X,
     *"SURFACE RUNOFF",15X,"= ",F7.2//
     *8X,"POTENTIAL EVAPORATION",17X,"= ",F7.2,28X,
     *"INTERFLOW THRU A HORIZON",5X,"= ",F7.2//
     *8X,"ESTIMATED ACTUAL EVAPORATION",10X,"= ",F7.2,28X,
     *"BASE FLOW",20X,"= ",F7.2//
     *9X,"EVAPORATION FROM DEPRESSION STORAGE  = ",F7.2,28X,
     *"LOSSES THRU SEEPS AND SPRINGS= ",F7.2//
     *9X,"EVAPORATION FROM A HORIZON STORAGE   = ",F7.2,28X,
     *"TOTALL SIMULATED RUNOFF",6X,"= ",F7.2//
     *9X,"EVAPORATION FROM B HORIZON STORAGE   = ",F7.2,28X,
     *"TOTAL OBSERVED RUNOFF",8X,"= ",F7.2//
     *8X,"GROUNDWATER RECHARGE",18X,"= ",F7.2)
   85 CONTINUE
      IF(N .LT. LDAY(ID,M))GO TO 82
      IF(M .EQ. 9) GO TO 84
      IF(IOPT .EQ. 1) GO TO 82
      WRITE(6,600)
      WRITE(6,17) ADATE
      WRITE(6,610)
      WRITE(6,45)
   84 CONTINUE
      DO 83 K=1,20
      TMW(K) = 0.0
   83 CONTINUE
   82 CONTINUE
C**
C**   END OF DAILY LOOP
C**
  100 CONTINUE
      IF(IOPT .EQ. 1) GO TO 65
      WRITE(6,600)
      WRITE(6,17) ADATE
      WRITE(6,488)
  488 FORMAT(///,
     *           1X,"THE FOLLOWING ARE ANNUAL TOTALS IN MILLIMETERS"/////)
      WRITE(6,490) (TOTALW(I),TOTALW(I+7),I=1,7),TOTALW(15)
      IF(NYRS .GT. 1) WRITE(6,600)
C**
C**   END OF YEARLY SIMULATION LOOP.
C**
C**   PERFORME STATISTICAL ANALYSIS AND COMPUTE OBJECTIVE FUNCTION.
   65 CONTINUE
      STATT = 0.0
      STATR = 0.0
      OBFN = 0.0
      SSLG = 0.0
      ABSV = 0.0
      SX = 0.0
      SXX = 0.0
      SY = 0.0
      SYY = 0.0
      SXY = 0.0
      NNYRT = 0
```

```
      IF(NOBSY  .EQ. 0) GO TO 74
      DO 68 J=1,NYRS
      NYR = BYEAR + J - 1
      NNYR = 365
      IF(MOD(NYR,4) .EQ. 0) NNYR = 366
      NNYRT = NNYRT + NNYR
      DO 68 I =1,NNYR
C**   CONVERT SIMULATED RUNOFF TO MILLIMETERS.
      QDAY(J,I) = QDAY(J,I)*86.4/SQKM
      STATT = STATT + OBMM(J,I) - QDAY(J,I)
      STATR = STATR + (OBMM(J,I) - QDAY(J,I))**2
      SX = SX + QDAY(J,I)
      SXX = SXX + QDAY(J,I)**2
      SXY = SXY + (QDAY(J,I) * OBMM(J,I))
      SY = SY + OBMM(J,I)
      SYY = SYY + OBMM(J,I)**2
      ABSV = ABSV + ABS(OBMM(J,I) - QDAY(J,I))
      OBFN = OBFN + ABS(OBMM(J,I) - QDAY(J,I))**EXPA/
     * (OBMM(J,I) + 0.00001)**EXPB
      SSLG = SSLG + (ALOG10((OBMM(J,I)+0.00001)/(QDAY(J,I)+0.00001)))**2
C**   CONVERT SIMULATED FLOWS TO CUBIC METERS PER SECOND.
C**   FLOWS ARE IN THESE UNITS WHEN RETURN TO MAIN PROGRAM.
      QDAY(J,I) = QDAY(J,I)*SQKM/86.4
   68 CONTINUE
C**   COMPUTE CORRELATION COEFFIENT.
      CCOF = (SXY - SX * SY/NNYRT)/
     * SQRT((SXX - SX**2/NNYRT) * (SYY - SY**2/NNYRT))
C**   COMPUTE SLOPE OF REGRESSION LINE.
      SLOPE = (SXY - SX * SY/NNYRT)/(SXX - SX**2/NNYRT)
C**   COMPUTE INTERCEPT OF THE REGRESSION LINE.
      YINT = SY/NNYRT - SLOPE*SY/NNYRT
      IF(EXPA .EQ. 0.0) OBFN = SSLG
      GO TO 69
   74 CCOF = 0.0
      SLOPE = 0.0
      YINT = 0.0
   69 CONTINUE
      IF(IOPT .EQ. 0) GO TO 101
      DO 92 K=1,NPAR
      OPPAR(K) = PRPAR(K)
   92 CONTINUE
C**   IOPT = 2  END OF PARAMETERS OPTIMIZATION.
      IF(IOPT .EQ. 2) GO TO 102
      CALL PAROPT
  102 CONTINUE
      IF(IROP .EQ. 0 .AND. NEND .EQ. 0) GO TO 110
      WRITE(6,94) (FPAR(K) ,K=1,LPAR)
      WRITE(6,96) (BPAR(K),K=1,NPAR),(UPPERL(K1),K1=1,NPAR),
     * (LOWERL(K2),K2=1,NPAR), (DELTA(K3),K3=1,NPAR)
  110 CONTINUE
      IF(NEND .EQ. 1) GO TO 55
      IF(IROP .EQ. 0) GO TO 120
      WRITE(6,97)(PRPAR(K),K=1,NPAR)
   97 FORMAT(//5X,"THE FOLLOWING IS THE OPTIMIZATION RESULT THIS RUN"//
     *         5X,"PARAMETER",10X,"FMAX",5X,"FMIN",5X,"ALFN",5X,
     *"AHORD",5X,"BHORP",5X,"FSRO",5X,"REXP",5X,"BHORD",5X,"EPAR",5X,
     * "DLOSS"//5X,"PRESENT VALUE",4X,10F9.3 /)
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```
      GO TO 101
   55 CONTINUE
      WRITE(6,47)(PRPAR(K),K=1,NPAR)
   47 FORMAT(//5X,"THE FOLLOWING IS THE FINAL OPTIMIZATION RESULTS"//
     *          5X,"PARAMETER",10X,"FMAX",5X,"FMIN",5X,"ALFN",5X,
     *"AHORD",5X,"BHORP",5X,"FSRO",5X,"REXP",5X,"BHORD",5X,"EPAR",5X,
     * "DLOSS"//5X,"BEST VALUE"    ,7X,10F9.3 /)
  120 CONTINUE
      IF(IROP .EQ. 0 .AND. NEND .EQ. 0) GO TO 115
  101 CONTINUE
      WRITE(6,98) EXPA,EXPB,STATT,STATR,SSLG,ABSV,OBFN,CCOF,SLOPE,YINT
   98 FORMAT(  /5X,"STATISTICS",9X
     *,"EXPA",6X,"EXPB",6X,"ERROR",5X,"SSERR",5X,"SSLOG",6X,"ABSV",6X,
     * "OBFN" ,6X, "CCOF" ,7X, "SLOPE" ,5X, "YINT"/20X,10F10.4/)
  115 CONTINUE
      IF(IOPT .EQ. 0) GO TO 500
      DO 11 K=1,NPAR
      PRPAR(K) = OPPAR(K)
   11 CONTINUE
      IF(NEND .EQ. 1) GO TO 500
      IF(IOPT .EQ. 2) GO TO 48
      GO TO 49
   48 NEND = 1
C**   NEND = 1  SIMULATE USING THE BEST OPTIMIZED PARAMETER VALUES.
      DO 93 K =1,NPAR
      PRPAR(K) = BETA(K)
   93 CONTINUE
      GO TO 49
  500 RETURN
      END
```

```
      SUBROUTINE PANEVP(J,TITLE,NYR)
C**   SUBROUTINE PPANEVP READ AND PRINT PAN EVAPORATION
C**   MEASUREMENTS FOR EACH WATER YEAR. JUNE 28,77
      DIMENSION ET(5,367),LDAY(2,12),NDAY(2,12),TITLE(10),PEC(12)
      DIMENSION PT(5,367)
      INTEGER BYEAR
      COMMON/SEA/ SQKM,ET,PT
      COMMON/EVAP/ LDAY,NDAY,EPAR,NEVP
      COMMON/RAIN/ADATE
      COMMON/SYN/ NYRS,BYEAR
C**   SELECT MONTHLY PAN COEFFICIENTS,PEC,SIMILAR TO
C**   THOSE USED IN SACRAMENTO CALIFORNIA(LD JAMES). JUNE 28,77
      DATA PEC/.60,.55,.60,.65,.75,.80,.85,.85,.80,.75,.70,.65/
C**   THE FIRST VALUE OF THE MONTHLY PAN EVP COEFF BELOW IS FOR JANUARY
      NNYR = 365
      IF(MOD(NYR,4) .EQ. 0) NNYR =366
C**   NEVP = 1 READ PAN EVAPORATION EACH YEAR.
C**   NEVP = 0 READ MEAN PAN EVAPORATION ONLY ONCE AND USE FOR EACH YR
      IF(NEVP .EQ. 0 .AND. J .GT. 1) GO TO 4
      READ(5,5) (ET(J,I),I=1,NNYR)
    5 FORMAT(10F8.0)
      GO TO 7
    4 ET(J,I) = ET(1,I)
    7 IF(NEVP .EQ. 1) GO TO 6
      WRITE(6,100) (TITLE(I),I=1,7)
  100 FORMAT(2X,"MEAN PAN EVAPORATION",6X,7A8,"VALUES IN MILLIMETERS")
      GO TO 15
    6 CONTINUE
      WRITE(6,110) NYR,(TITLE(I),I=1,7)
  110 FORMAT(2X,"PAN EVAPORATION FOR YEAR 19",I2,6X,7A8,"VALUES IN MILLI
     1METERS")
   15 CONTINUE
      CALL PRINT(NNYR,J,ET,1)
      RETURN
C**   COMPUTE DAILY POTENTIAL EVAPORATION. USE THE MONTHLY PAN
C**   COEFFICIENTS,PEC(MM), IN ORDER TO CONVERT PAN TO POT. ET. JUNE 28
      ENTRY POTEVP
      DO 10 M =1,12
      MM = M + 12
      IF(MM .GT. 12) MM=MM-12
      ID = 2
      IF(MOD(NYR,4) .EQ. 0) ID = 1
      LD = LDAY(ID,MM)
      DO 20 JJ = 1,LD
      JK = NDAY(ID,MM) + JJ
      PT(J,JK) = ET(J,JK)*PEC(MM)
   20 CONTINUE
   10 CONTINUE
      RETURN
      END
```

```
      C**   SUBROUTINE PAROPT
            SUBROUTINE PAROPT
      C PATTERN SEARCH OPTIMIZATION -J.C.MONRO-NATIONAL WEATHER SERVICE
      C  MODIFIED BY F.L. CURRIE AND A.M. LUMB
      C**   MODIFIED  AND ADOPTED TO THE JORDAN WATERSHED MODEL BY AA SAAD
            COMMON/OPTM/IOPT,A(10),PRPAR(10),DDELTA(10),CHECKL(10),CHECKH(10),
           *OPTIM,NUMA,NSTART,NPER,KC,MAXN,EXPA,EXPB
           * ,BETA(10),IROP
            DIMENSION DELTA(10),BA(10),B(10),NSIGN(10),LES(10),ICLOSL(10),
           *ICLOSH(10)
            IF(NSTART.GT.0) GO TO 2
      C INITIALIZE
            DO 1 I=1,NUMA
            LES(I) = 0
            BA(I) = A(I)
            B(I) = A(I)
            ICLOSL(I) = 0
            ICLOSH(I) = 0
            IF(NPER.GT.0) GO TO 100
            DELTA(I) = DDELTA(I)
            GO TO 101
        100 DELTA(I) = ABS(DDELTA(I)*A(I))
        101 IF(A(I).GT.CHECKH(I)) GO TO 3000
            IF(A(I).LT.CHECKL(I)) GO TO 3000
            CC = A(I)-1.01*DELTA(I)
            CD = A(I)+1.01*DELTA(I)
            IF(CC.GT.CHECKL(I)) GO TO 1500
            ICLOSL(I) = 1
            A(I) = BA(I)
       1500 IF(CD.LT.CHECKH(I)) GO TO 1
            ICLOSH(I) = 1
            A(I) = BA(I)
          1 CONTINUE
            PRINT 1000
       1000 FORMAT(1H1)
            LC = 0
            IT = 1
            IZY = 0
            NN = 0
            NCOUN = 1
            ICOUN = 0
            IFIRS = 0
            LDELT = 0
            NSTART = 1
            NSAVE = 0
          2 YS = OPTIM
            NN = NN + 1
            IF(NN .NE. MAXN .AND. IROP .EQ. 0) GO TO 60
            PRINT 1000
            PRINT 55,NCOUN,NN
            WRITE(6,1610)OPTIM
       1610 FORMAT(/5X,"OPTIMIZATION CRITERIA (THIS RUN)",11X,F10.6)
         60 CONTINUE
            ZZ = YY
            IF(YX.LT.YY) ZZ = YX
            IF(NN .NE. MAXN .AND. IROP .EQ. 0) GO TO 65
            WRITE(6,1611)ZZ
```

```
 1611 FORMAT(/5X,"OPTIMIZATION CRITERIA (BEST PRIOR RUN)",5X,F10.6)
   65 CONTINUE
      IF(IFIRS.EQ.1) GO TO 4
      YX = OPTIM
      YY = YX
      IFIRS = 1
    4 CONTINUE
   55 FORMAT(/5X,"TRIAL",I4,5X,"RUN",I4)
      IF(NN .GE. MAXN) GO TO 7000
   44 IF(LES(IT).EQ.1) GO TO 14
      IF(IZY.GT.0) GO TO 8
      IF(YS.GT.YY) GO TO 1008
      NSAVE = 1
      YX = YS
      YY = YS
 1008 CONTINUE
    6 IZY = IZY + 1
      IT = IZY
      IF(LES(IZY).EQ.1) GO TO 107
  108 LL = 0
C  LOCAL EXCURSION ROUTINE  (+DELTA(I) FIRST)
      A(IZY) = A(IZY) + DELTA(IZY)
      NSIGN(IZY) = 0
      IF(ICLOSH(IZY).EQ.0) GO TO 7
      LL = LL + 1
      GO TO 88
    7 LL = LL + 1
      GO TO 6000
    8 IF(YX.GT.YS) GO TO 11
   88 GO TO(9,10,12),LL
    9 A(IZY) = A(IZY) - 2.0*DELTA(IZY)
      NSIGN(IZY) = 1
      IF(ICLOSL(IZY).EQ.1) GO TO 10
      GO TO 7
   10 A(IZY) = A(IZY) + DELTA(IZY)
      NSIGN(IZY) = 0
      GO TO 12
   11 YX = YS
C**   SAVE THE PARAMETER VALUES OF THE BEST PRIOR RUN.
      DO 50 I=1,NUMA
      BETA(I) = A(I)
   50 CONTINUE
   12 IF(IZY.LT.NUMA) GO TO 6
      IT = 1
      IZY = 0
      IF((1.001*YX).GE.YY) GO TO 25
      YY = YX
      GO TO 210
C LOCAL EXCURSION  (-DELTA(I) FIRST)
   14 IF(IZY.GT.0) GO TO 16
      IF(YS.GT.YY) GO TO 1007
      NSAVE = 1
      YX = YS
      YY = YS
 1007 CONTINUE
  106 IZY = IZY + 1
      IT = IZY
```

```
      IF(LES(IZY).EQ.0) GO TO 108
  107 LL = 0
      A(IZY) = A(IZY) - DELTA(IZY)
      NSIGN(IZY) = 1
      IF(ICLOSL(IZY).EQ.0) GO TO 15
      LL = LL + 1
      GO TO 166
   15 LL = LL + 1
      GO TO 6000
   16 IF(YX.GT.YS) GO TO 19
  166 GO TO(17,18,20),LL
   17 A(IZY) = A(IZY) + 2.0*DELTA(IZY)
      NSIGN(IZY) = 0
      IF(ICLOSH(IZY).EQ.1) GO TO 18
      GO TO 15
   18 A(IZY) = A(IZY) - DELTA(IZY)
      NSIGN(IZY) = 1
      GO TO 20
   19 YX = YS
C**   SAVE THE PARAMETER VALUES OF THE BEST PRIOR RUN.
      DO 45 I=1,NUMA
      BETA(I) = A(I)
   45 CONTINUE
   20 IF(IZY.LT.NUMA) GO TO 106
      IT = 1
      IZY = 0
      IF((1.001*YX).GE.YY) GO TO 25
      YY = YX
C
  210 IF(NPER.EQ.0) GO TO 22
      DO 21 I=1,NUMA
      DELTA(I) = ABS(DDELTA(I)*A(I))
   21 CONTINUE
   22 LC = 0
      NSAVE = 0
      PRINT 220
  220 FORMAT(//21X,"PATTERN MOVE")
      NCOUN = NCOUN + 1
C  PATTERN MOVE ROUTINE
      DO 24 I =1,NUMA
      LES(I) = NSIGN(I)
      BA(I) = A(I)
      A(I) = 2.0*A(I)-B(I)
C CHECK UPPER AND LOWER CONSTRAINTS
      CC = A(I)-1.01*DELTA(I)
      CD = A(I)+1.01*DELTA(I)
      IF(CC.GT.CHECKL(I)) GO TO 103
      ICLOSL(I) = 1
      A(I) = BA(I)
      GO TO 104
  103 ICLOSL(I) = 0
  104 IF(CD.LT.CHECKH(I)) GO TO 105
      ICLOSH(I) = 1
      A(I) = BA(I)
      GO TO 23
  105 ICLOSH(I) = 0
   23 B(I) = BA(I)
```

```
   24 CONTINUE
      GO TO 6000
C
   25 LC = LC + 1
      IF (YX.LT.YY) GO TO 28
C DESTROY PRESENT PATTERN
      IF(LC-1)7000,26,28
   26 IF(NSAVE.EQ.1) GO TO 260
      DO 27 I=1,NUMA
      A(I) = BA(I)
   27 CONTINUE
      ICOUN = ICOUN + 1
      GO TO 30
   28 IF(LDELT.GE.KC) GO TO 7000
C HALVE DELTA(I)  (RESOLUTION)
  260 NSAVE = 0
      DO 29 I = 1,NUMA
      DDELTA(I) = DDELTA(I)*0.5
      DELTA(I) = DELTA(I)*0.5
      CC = A(I)-1.01*DELTA(I)
      CD = A(I)+1.01*DELTA(I)
      IF(CC.GT.CHECKL(I)) ICLOSL(I) = 0
      IF(CD.LT.CHECKH(I)) ICLOSH(I) = 0
   29 CONTINUE
      LDELT = LDELT + 1
   30 PRINT 31,ICOUN,LDELT
   31 FORMAT(//20X,"PATTERN=",I4,"   RESOLUTION=",I5)
      GO TO 44
 6000 RETURN
 7000 CONTINUE
      IOPT = 2
      RETURN
 3000 PRINT 5000,I
 5000 FORMAT(5X,"ERROR ** THE INITIAL VALUE OF PARAMETER NO ",I2," ",
     *"IS GT ITS UPPER LIMIT OR LT ITS LOWER LIMIT"/
     *5X,"CHECK ALL PARAMETER  VALUES AND THEIR UPPER AND LOWER LIMITS.
     *MAKE APPROPRIATE CORRECTIONS AND RESTART")
      STOP
      END
```

```
C**   SUBROUTINE TO PRINT OUT DAILY FLOWS RAINFALL AND PAN EVAPORATION.
C**
      SUBROUTINE PRINT(NNYR,J,RESULT,KK)
      DIMENSION RESULT(5,367),TOTAL(12)
C**   ADD COMMON TO COMPUTE TOTAL FLOWS IN MILLIMETERS. MAY 24,77
      COMMON/SEA/ SQKM
      RESULT(J,367)=0.0
      ANNUAL=0.0
C**     ANUALM = ANNUAL STREAMFLOW IN MILLIMETERS. MAY 28,77
      ANUALM = 0.0
      DO 10 I=1,12
      TOTAL(I)=0.0
   10 CONTINUE
      L=0
      L11=0
      L2=0
      L4=0
      L6=0
      L9=0
      IF(NNYR.EQ.366)L=1
      WRITE(6,75)
   75 FORMAT("0",1X,"DAY",2X,"OCT.",6X,"NOV.",6X,"DEC.",6X,"JAN.",6X,"FE
     1B.",6X,"MAR.",6X,"APR.",7X,"MAY",6X,"JUNE",6X,"JULY",6X,"AUG.",6X,
     2"SEPT.",4X,"DAY"/)
      DO 60 N=1,31
      IF(N.GT.(28+L)) L2=244-N
      IF(N.LT.31) GO TO 20
      L11=305
      L4=154-L
      L6=93-L
      L9=1-L
   20 TOTAL(1)=TOTAL(1)+RESULT(J,N)
      TOTAL(2)=TOTAL(2)+RESULT(J,(31+N+L11))
      TOTAL(3)=TOTAL(3)+RESULT(J,(61+N))
      TOTAL(4)=TOTAL(4)+RESULT(J,(92+N))
      TOTAL(5)=TOTAL(5)+RESULT(J,(123+N+L2))
      TOTAL(6)=TOTAL(6)+RESULT(J,(151+N+L))
      TOTAL(7)=TOTAL(7)+RESULT(J,(182+N+L+L4))
      TOTAL(8)=TOTAL(8)+RESULT(J,(212+N+L))
      TOTAL(9)=TOTAL(9)+RESULT(J,(243+N+L+L6))
      TOTAL(10)=TOTAL(10)+RESULT(J,(273+N+L))
      TOTAL(11)=TOTAL(11)+RESULT(J,(304+N+L))
      TOTAL(12)=TOTAL(12)+RESULT(J,(335+N+L+L9))
C**
      WRITE(6,65)N,RESULT(J,N),RESULT(J,(31+N+L11)),RESULT(J,(61+N)),RES
     1ULT(J,(92+N)),RESULT(J,(123+N+L2)),RESULT(J,(151+L+N)),RESULT(J,(1
     282+L+N+L4)),RESULT(J,(212+L+N)),RESULT(J,(243+L+N+L6)),RESULT(J,(2
     373+L+N)),RESULT(J,(304+L+N)),RESULT(J,(335+L+N+L9)),N
C**   PRINT STREAMFLOWS IN CUBIC METERS PER SECOND. MAY 23,77
   65 FORMAT(I4,F8.3,11F10.3,I6)
   60 CONTINUE
      DO 30 M=1,12
   30 ANNUAL=ANNUAL+TOTAL(M)
C**   SET KK EQUALS 1 TO PRINT RAINFALL DATA  AND SET KK EQUAL 2
C**   TO PRINT STREAMFLOW DATA . MAY 23,77
C**   SET KK EQUAL 1 TO PRINT PAN EVAPORATION. MAY 28,77
      IF(KK .EQ. 2) GO TO 70
```

```
      WRITE(6,40) (TOTAL(M),M=1,12) ,ANNUAL
      GO TO 80
   70 ANUALM = ANNUAL*86.4/SQKM
      WRITE(6,50) (TOTAL(M),M=1,12) ,ANNUAL,ANUALM
   80 CONTINUE
   50 FORMAT(///1X,"TOTAL ",F6.3,F9.3,10F10.3,///1X,
     1"TOTAL FOR WATER YEAR = "
     1,F10.3," CUBIC METERS PER SECOND"//21X," =",F10.2," MILLIMETERS")
   40 FORMAT(///1X,"TOTAL",F6.2,11F10.2///1X,"TOTAL FOR WATER YEAR = "
     1 ,F10.2,"  MILLIMETERS")
      RETURN
      END
```

```
      SUBROUTINE PLOTA(OBSY,PREDY,RF,NOBS,L,MD)                         PLOTA    1
C**   SUBROUTINE TO PLOT FLOWS AND RAINFALL ON ARITHMATIC SCALE.        PLOTA    2
C**   ORGINAL BY REEVES AND MODIFIED BY LUCAS,FIELDS,ORNL.              PLOTA    3
C**   MODIFIED BY ADNAN A SAAD FOR USAGE IN JORDAN MODEL.               PLOTA    4
      COMMON /SEA/ SQKM                                                 PLOTA    5
      COMMON /EVAP/ LDAY,NDAY                                           PLOTA    6
      DIMENSION LDAY(2,12),NDAY(2,12)                                   PLOTA    7
      DIMENSION OBSY(5,367),PREDY(5,367),KR(102),KS(3),                 PLOTA    8
     1 RF(5 ,367),OBSYM(5 ,367),PREDYM(5 ,367)                          PLOTA    9
      DATA KS/"R","O","S"/                                              PLOTA   10
      DATA KSR/"*"/,KGRD/"!"/,KBK/" "/                                  PLOTA   11
C**   CONVERT TO METRIC  SYSTEM-CHANGE SCALE AND FORMAT.DATE MAR. 3,77  PLOTA   12
      YMIN=0.0                                                          PLOTA   13
      YMAX=0.0                                                          PLOTA   14
      RMAX=0.0                                                          PLOTA   15
      DO 77 J=1,NOBS                                                    PLOTA   16
      RMAX=AMAX1(RMAX,RF(L,J))                                          PLOTA   17
   77 YMAX=AMAX1(YMAX,OBSY(L,J),PREDY(L,J))                             PLOTA   18
C**   READ RUNOFF PLOTTING SCALE IN ORDER TO MAGNIFY LOW FLOWS.         PLOTA   19
C**   RUNOFF FULL SCALE IS EQUAL TO THE MAX. OF EITHER OBS OR SIM FLOW. PLOTA   20
      READ (5,2) YMAXR                                                  PLOTA   21
    2 FORMAT(F5.0)                                                      PLOTA   22
      IF(YMAXR .EQ.0.0)YMAXR = YMAX                                     PLOTA   23
      YMAX = YMAXR                                                      PLOTA   24
      ZMIN=0.0                                                          PLOTA   25
      ZMAX=YMAX                                                         PLOTA   26
      RFMAX = 100.0                                                     PLOTA   27
      IF(RMAX .LE. 50.0) RFMAX =50.0                                    PLOTA   28
      WRITE(MM,990) YMAX                                                PLOTA   29
  990 FORMAT(//1X,"GRAPH RUNOFF FULL SCALE = ",F7.3," CUBIC METERS/SEC")PLOTA   30
      WRITE(MM,991) RFMAX                                               PLOTA   31
  991 FORMAT("+",60X,"RAINFALL FULL SCALE = ",F4.0," MILLIMETERS"//)    PLOTA   32
      DO 1 I=1,51                                                       PLOTA   33
    1 KR(I) = KSR                                                       PLOTA   34
      WRITE(MM,1000) KSR,(KR(I),I=1,51),KSR                             PLOTA   35
 1000 FORMAT(1X,"MO",2X,"DAY",3X,"RAIN",6X,"OBS",5X,"SIM",6X,"OBS",     PLOTA   36
     *5X,"SIM",19X,53A1,2X,"RAIN,MM")                                   PLOTA   37
      M = 10                                                            PLOTA   38
      IM = 2                                                            PLOTA   39
      IF(NOBS .EQ. 366) IM = 1                                          PLOTA   40
      DO 7 JP=1,NOBS                                                    PLOTA   41
C**   LIST FLOWS BY DAY AND MONTH.                                      PLOTA   42
      N = JP - NDAY(IM,M)                                               PLOTA   43
      IF(N .LE. LDAY(IM,M))GO TO 5                                      PLOTA   44
      M = M + 1                                                         PLOTA   45
      IF(M .GT. 12) M = M - 12                                          PLOTA   46
    5 CONTINUE                                                          PLOTA   47
      N = JP - NDAY(IM,M)                                               PLOTA   48
      J = JP                                                            PLOTA   49
      DO 3 I = 1,51                                                     PLOTA   50
    3 KR(I) = KBK                                                       PLOTA   51
      DO 4 I=6,46,5                                                     PLOTA   52
    4 KR(I) = KGRD                                                      PLOTA   53
      D=RFMAX-YMIN                                                      PLOTA   54
      IF(D.LE.0) D=1                                                    PLOTA   55
      AI=50.*(RF(L,J)-YMIN)/D                                           PLOTA   56
      AI=50.-AI                                                         PLOTA   57
```

```
      AIP = FLOAT(IFIX(AI))
      IF((AI-AIP).GE..5) AI=AI+1
      I=AI+1.0
      IF(I.LT.1) I=100
      IF(I.GT.100) I=100
      KR(I)=KS(1)
      D = YMAX-YMIN
      IF(D.LE.0) D=1
      AI = 50.*(OBSY(L,J)-YMIN)/D
      AIP = FLOAT(IFIX(AI))
      IF  ((AI-AIP).GE..5) AI=AI+1
      I  =AI+1.
      IF  (I.LT.1) I=100
      IF  (I.GT.100) I=100
      KR(I)  =KS(2)
      D  =ZMAX-ZMIN
      IF(D.LE.0) D=1
      AI = 50.*(PREDY(L,J)-ZMIN)/D
      AIP = FLOAT(IFIX(AI))
      IF  ((AI-AIP).GE..5) AI=AI+1.
      I  =AI+1.
      IF  (I.LT.1) I=100
      IF  (I.GT.100) I=100
      KR(I)  =KS(3)
C**
C**   PRINT OBSERVED AND SIMULATED FLOWS IN CU METER PER SEC AND IN MM.
      OBSYM(L,J) = OBSY(L,J)* 86.4/SQKM
      PREDYM(L,J) = PREDY(L,J)*86.4/SQKM
      IF(RF(L,J) - 0.001) 10,10,20
C**   PRINT DAILY RAINFALL IN FLOWS TABLE. MAY 25,77
   10 WRITE(6,1001) M,N,RF(L,J),OBSY(L,J),PREDY(L,J),OBSYM(L,J),
     *PREDYM(L,J),KSR,(KR(K),K=1,51),KSR
      GO TO 7
   20 WRITE(6,1001) M,N,RF(L,J),OBSY(L,J),PREDY(L,J),OBSYM(L,J),
     *PREDYM(L,J),KSR,(KR(K),K=1,51),KSR,RF(L,J)
C**   CHANGE FORMAT STATEMENTS FROM D 8 E TO F . DATE FEB. 14,77
 1001 FORMAT(I3,I4,3X,F5.1,1X,2F8.3,2X,2F8.4,18X,53A1,2X,F5.1)
    7 CONTINUE
      DO 8 I=1,51
    8 KR(I) = KSR
      WRITE(MM,1002)KSR,(KR(I),I=1,51),KSR
 1002 FORMAT(68X,53A1)
      RETURN
      END
```

```
      SUBROUTINE PLOTL(IDY,PLTR,M,J,IPLOTL)
C**   SUBROUTINE PLOTL- PLOTTING SIMULATED AND OBSERVED FLOW
C**   IN LOG SCALE. DATE FEB. 18,77
      COMMON /MP/DP(12,31)
      DIMENSION ICHAR(123),PLTR(2,31),MMTH(5,12)
      DATA IOBS/"O"/
      DATA IBLK/" "/
      DATA ICAL/"S"/
      DATA IDSH/"!"/
      DATA MMTH/" ","J","A","N","."," ","F","E","B",".","M","A","R","C",
     1"H","A","P","R","I","L"," ","M","A","Y"," "," ","J","U","N","E",
     2" ","J","U","L","Y"," ","A","U","G",".","S","E","P","T","."," ",
     3"O","C","T","."," ","N","O","V","."," ","D","E","C","."/
C**   CONVERT FORMAT AND SCALE TO METRIC. DATE MARCH 7,77
      IF(IPLOTL .EQ. 0) GO TO 110
      DO 100 ID =1,IDY
      DO 90 K =1,123
   90 ICHAR(K) = IBLK
      DIL = 30.00
      IDL = DIL
      SPL = 2.0*DIL + 2.49
      DO 92 K =2,122,IDL
   92 ICHAR(K) = IDSH
      PMIN = 0.01
      PMAX = 100.0
      IF(J .EQ. 0) GO TO 10
      PMIN = 0.10
      PMAX = 1000.00
   10 CONTINUE
      DO 15 JJ=1,2
      IF(PLTR(JJ,ID) .GE. PMIN) GO TO 20
      ICHAR(1) = ICAL
      IF(JJ .EQ. 1) ICHAR(1) = IOBS
      PLTR(JJ,ID) = PMIN
   20 CONTINUE
      IF(PLTR(JJ,ID) .LE. PMAX) GO TO 25
      ICHAR(123) = ICAL
      IF(JJ .EQ. 1) ICHAR(123) = IOBS
      PLTR(JJ,ID) = PMAX
   25 CONTINUE
      N = DIL*ALOG10(PLTR(JJ,ID)) + SPL
      IF(J .EQ. 1) N = N - IDL
      ICHAR(N) = ICAL
      IF(JJ .EQ. 1) ICHAR(N) = IOBS
   15 CONTINUE
      MC = IBLK
      IF(ID.LE.5.AND.M.LE.12) MC = MMTH(ID,M)
      IF(DP(M,ID) - 0.005) 98,98,99
   98 WRITE(6,200) MC,ID,(ICHAR(K),K=1,123)
  200 FORMAT(1X,A1,I2,123A1,F8.2)
      GO TO 100
   99 WRITE(6,200) MC,ID,(ICHAR(K),K=1,123),DP(M,ID)
  100 CONTINUE
  110 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE CPLOT(NYRS,NNYR,J,O,S,LOGS)
C**
C**   PLOTTING SCALES ARE SELECTED FOR SPICIFIC CASES.
C**   USERS SHOULD SELECT APPROPRIATE SCALE FOR THEIR JOBS.
C**
C**   THIS SUBROUTINE PROVIDES CALCOMP PLOTS OF OBS AND SIM FLOWS.
C**   ALL ROUTINES CALLED ARE AVAILABLE ON THE CDC CYBER 74.
      INTEGER NAME(12)
      DIMENSION TEMP(370),BUF(512),DAY(370),O(5,367),S(5,367)
      DATA NAME/ 3HOCT,3HNOV,3HDEC,3HJAN,3HFEB,3HMAR,3HAPR,3HMAY,3HJUN,
     *3HJUL,3HAUG,3HSEP/
      IF(J .EQ. 1) CALL PLOTS(BUF,512,3,0)
C**   PLOT 11.0 INHES BY 8.5 INHES LINE FRAME
      CALL PLOT(0.0,0.0,3)
      CALL PLOT(11.0,0.0,2)
      CALL PLOT(11.0,8.5,2)
      CALL PLOT(0.0,8.5,2)
      CALL PLOT(0.0,0.0,2)
      CALL PLOT(1.0,1.0,-3)
      XLEN = 9.00
      YLEN = 6.00
      DO 10 I=1,NNYR
   10 DAY(I) = FLOAT(I)
C**   SELECT X-AXIS SCALE (INITIAL VALUE AND INCREMENT PER INCH).
      DAY(NNYR+1) = 1.00
      DAY(NNYR+2) = 41.00
      DO 100 I=1,NNYR
  100 TEMP(I) = O(J,I)
      IF(LOGS .EQ. 1) GO TO 20
C**   SELECT STREMFLOW PLOTTING SCALE FOR ARITHMATIC PLOT
C**   SELECT INITIAL VALUE AND INCREMENT PER INCH
      TEMP(NNYR+1) = 0.0
      IF(J .EQ. 1) TEMP(NNYR+2) = 15.00
      IF(J .EQ. 2) TEMP(NNYR+2) = 4.00
      IF(J .EQ. 3) TEMP(NNYR+2) = 20.00
      IF(J .EQ. 4) TEMP(NNYR+2) = 6.00
      IF(J .EQ. 5) TEMP(NNYR+2) = 5.00
      GO TO 30
C**   SELECT STREAMFLOW PLOTTING SCALE FOR LOGARITHMIC PLOT
C**   SELECT INITIAL VALUE AND LOG CYCLE PER INCH
   20 TEMP(NNYR+1) = 0.10
      TEMP(NNYR+2) = 0.50
   30 CONTINUE
C**   PLOT 9.00 INCHES BY 6.00 INCHES LINE FRAME
      CALL PLOT(0.0,0.0,3)
      CALL PLOT(XLEN,0.0,2)
      CALL PLOT(XLEN,YLEN,2)
      CALL PLOT(0.0, YLEN,2)
      CALL PLOT(0.0,0.0,2)
      CALL PLOT(0.0,-0.10,2)
      XTOTAL = FLOAT(NNYR)/DAY(NNYR+2)
      XMTH = XTOTAL/12.0
      X10DAY = XMTH/3.0
      DO 50 JJ=1,12
      DO 40 K =1,2
      Z =(JJ-1)*XMTH + K*X10DAY
      CALL PLOT(Z,0.0,3)
```

```
   40 CALL PLOT(Z,-0.05,2)                                          CPLOT   58
      Z = (JJ-1)*XMTH + 1.25*X10DAY                                 CPLOT   59
      CALL SYMBOL(Z,-0.20,0.07,NAME(JJ),0.0,3)                      CPLOT   60
      Z = JJ*XMTH                                                   CPLOT   61
      CALL PLOT(Z,0.0,3)                                            CPLOT   62
      CALL PLOT(Z,-0.10,2)                                          CPLOT   63
   50 CONTINUE                                                      CPLOT   64
      IF(LOGS .EQ. 0) CALL AXIS  (0.0,0.0,"DAILY STREAMFLOW IN CU METERSCPLOT   65
     * PER SEC",37,YLEN,90.0,TEMP(NNYR+1),TEMP(NNYR+2))             CPLOT   66
      IF(LOGS .EQ. 1) CALL LGAXIS(0.0,0.0,"DAILY STREAMFLOW IN CU METERSCPLOT   67
     * PER SEC",37,YLEN,90.0,TEMP(NNYR+1),TEMP(NNYR+2))             CPLOT   68
C**   PLOT OBSERVED FLOW ON ARITHMATIC SCALE                        CPLOT   69
      IF(LOGS .EQ. 0) CALL LINE(DAY,TEMP,NNYR,1,0,0)                CPLOT   70
C**   PLOT OBSERVED FLOW ON LOGARITHMIC SCALE                       CPLOT   71
      IF(LOGS .EQ. 1) CALL LGLINE(DAY,TEMP,NNYR,1,0,12,1)           CPLOT   72
      DO 60 I=1,NNYR                                                CPLOT   73
   60 TEMP(I) = S(J,I)                                              CPLOT   74
C**   PLOT SIMULATED FLOW ON ARITHMATIC SCALE                       CPLOT   75
      IF(LOGS .EQ. 0) CALL DASHLN(DAY,TEMP,NNYR,1)                  CPLOT   76
C**   PLOT SIMULATED FLOW ON LOGARITHMIC SCALE                      CPLOT   77
      IF(LOGS .EQ. 1) CALL LGLINE(DAY,TEMP,NNYR,1,1,15,1)           CPLOT   78
      CALL SYMBOL(6.0,4.00,.105,"SOLID LINE = OBSERVED FLOW",0.0,26) CPLOT   79
      CALL SYMBOL(6.0,3.75,.105,"DASHED LINE = SIMULATED FLOW",0.0,28) CPLOT 80
      CALL PLOT(XLEN+3.0,-1.0,-3)                                   CPLOT   81
      IF(J .EQ. NYRS)  CALL PLOT(XLEN+3.0,0.0,999)                  CPLOT   82
      RETURN                                                        CPLOT   83
      END                                                           CPLOT   84
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VITA

Adnan Ahmad Saad was born in Um Alfahm, Palestine in January 19, 1943. He attended Primary and Secondary schools in Jordan and Kuwait. His undergraduate education was pursued at Ain Shams University, Cairo, Egypt where he obtained a Bachelor of Science degree in Civil Engineering, Structure Division in 1966. During the summer months of the study period, he was trained on various civil engineering projects, such as highways and bridges, in Kuwait and Germany. The author started his professional career with the Ministry of Public Works in Kuwait as a site engineer responsible for the construction of three development projects. In 1969 he undertook graduate studies in soil mechanics and groundwater hydrology at the University of Delaware. He obtained a Master of Civil Engineering degree in 1971. The master's thesis title is "Electric Analog Model for the Piney Point Aquifer, Kent County, Delaware." After completion of the first stage of graduate studies, the author returned to practice with John J. Harte Associates, Inc., an Atlanta based consulting firm in the field of hydraulics and hydrology. His major assignments include planning and designing water resources projects such as earth fill dams, master drainage plans, flood plain studies and various hydrologic analysis of river basins.

During his professional career, on a part-time basis, he pursued graduate studies at the Georgia Institute of Technology for the degree of Doctor of Philosophy in the School of Civil Engineering. His primary interest is in streamflow simulation modeling. The scope of his doctoral research work is to develop a watershed model enabling streamflow simulation in a semi-arid region. Presently, the author is in charge of the Hydraulic and Hydrology Division at John J. Harte Associates, Inc. He is a registered professional engineer and a member of the Georgia Society of Professional Engineers, the National Society of Professional Engineers, the American Society of Civil Engineers, the American Geophysical Union, and the U. S. Committee on Irrigation, Drainage and Flood Control of the International Commission on Irrigation and Drainage. He is married and has one daughter.